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# STUDIES OF THE EFFECTS OF SONIC BOOM ON BIRDS

James G. Teer, et al

James G. Teer and Company

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# STUDIES OF THE EFFECTS OF SONIC BOOM ON BIRDS

James G. Teer Joe C. Truett

James G. Teer and Company
1204 Walton Drive
College Station, Texas 77840



SEPTEMBER 1973

FINAL REPORT



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16. Abstract A field study was carried out near Glen Rose, Texas to try to discover if occurence of sonic booms created by overflying aircraft was adversely affecting reproduction of wild birds. Several measures of reproductive success in mourning doves, mockingbirds, cardinals, and lark sparrows were compared between a test area and a control area. The test area was subject to sonic booms occurring 2 or 3 times a week; the control area was essentially free from sonic boom disturbance.

Some differences in various phases of reproductive success were found between the 2 areas. However, none of the comparisons indicated that the differences were caused by other than natural environmental factors. In the final analysis, the authors could find no evidence that sonic boom disturbance affected phases of bird reproduction studied in the program.

Studies of the effects of pressure on growth, reproduction and mortality of bobwhite quail were made in the laboratory with equipment designed to deliver pressure treatments under controlled conditions. Tests were made of the hypotheses that pressures similar to those delivered by aircraft flying at supersonic speeds would reduce hatching success, change growth rates, and increase mortaility of chicks hatched from eggs subjected to such pressures. A total of 7,425 eggs were placed in four incubators and carried through to hatching. Chicks hatched from these eggs were carried through to 12 weeks of age. Pressure of 2.0 PSF, 4.0 PSF, and 5.5 PSF were delivered to the incubating eggs at 3 frequencies each day for 18 days.

Results of these experiments showed that the pressures had no effects on hatching success, growth rates, or mortality.

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## SECTION I. FIELD STUDIES

# A STUDY OF THE EFFECTS OF SONIC BOOM ON GROWTH AND REPRODUCTION OF WILD BIRDS


Conducted by

Dr. Joe C. Truett


March 1, through August 15, 1973

## INTRODUCTION

This report attempts to assess possible adverse effects to reproduction and early growth of free-nesting wild birds as a consequence of overflights of aircraft at supersonic speeds. Experimentation upon which the report is based was conducted by Dr. Joe C. Truett and Dr. James G. Teer under a cooperative agreement with the Federal Aviation Administration (FAA).

Field studies were performed in spring and early summer, 1973, in Somervell and osque Counties, Texas, about 50 miles southwest of the Fort Worth-Dallas metropolitan area. Experiments were designed to appraise reproductive success and early growth in birds on a test site, subjected to periodic "sonic booms" created by overflying aircraft, and on a control site not affected by sound and pressure changes produced by "booms". Final evaluations of factors influencing productivity of bird populations on the test area were made with comparative data from the control area at hand. The primary objective was to isolate possible influences to normal reproduction and growth that could not be relegated to "natural" causes.

## METHODS OF STUDY

### Selection of Study Sites

A test site and a control site on which to conduct nesting studies were selected. Although exact duplication of habitat type was not possible, the areas chosen were as alike in soil parent material, vegetation type and cultural practices important to bird productivity (farming, water supply) as could be found in the time available for site selection.

Test Area

The test area was selected on two bases: (1) accessibility, and (2) nearness to the flight path of supersonic aircraft originating from Carswell Air Force Base. Figure 1 shows the geographic location of the flight path of these supersonic aircraft near Glen Rose in Somervell County. This plotted flight path was provided by the FAA. The three sites used collectively as a test area are shown in relation to the flight path.

Area A, the main study site, was property owned by Texas Utilities Services, Inc. Some additional information was gathered on the Glen Rose Golf Course (Area B) and on the northern end of Dinosaur Valley State Park (Area C) during May and June.

Control Area

The Parks Ranch in Bosque County, near Highway 22 between Meridian and Cranfills Gap, was chosen as a control site (Figure 2).

Reasons for selecting the Parks Ranch as a control site were: (1) It was far enough away from the supersonic flight path (approximately 29 airline miles) to be essentially free from aircraft-generated sound and pressure-change disturbance (pers. comm., Col. Jamey Jameson, FAA, Meacham Air Field, Ft. Worth, Texas), (2) It was close enough to the test area to preclude the necessity for extensive travel between the two areas, (3) unobstructed access to a fairly large land area (5,000 acres) was available there, and (4) most important, soils, vegetation types, and bird species present were very similar to those on the test area.

Monitoring of Sonic Boom Disturbance

Instrumentation to measure the frequency and intensity of sonic booms along the flight path near Glen Rose was in operation at the Post Office Building in Glen Rose, and at the Bar L Ranch 6 miles NWW of Glen Rose (Figure 1). Data from these FAA-operated stations were used as a measure of the frequency of sonic booms to which the test areas were subjected. Occurrence of all pressure changes of one pound per square foot and greater at these stations were tabulated. Model 529 Sonic Boom Detectors (Figure 3) were used at these stations for recording booms. These detectors were manufactured by Telephonics Instruments Systems in Huntington, New York.

Five sonic boom detectors of the same model were provided by the FAA for installation on the study areas. Originally three of these detectors were put on the control area and two on the test area (the first week in April). Subsequent experience indicated that considerable malfunctioning of these detectors could be expected, so all functional units were kept on the control area after mid-April. These portable detectors were maintained on the control area until the termination of field study so that any sonic boom disturbance to that area could be monitored.

Ascertaining Reproduction and Growth of Birds.

During early March, both the test area and the control area were systematically searched to (1) familiarize myself with the distribution of vegetation types and subtypes on the areas, (2) find the distribution by habitat type of old bird nests, particularly of the species selected for study, and (3) look for bird nests in use.

As soon as birds began nesting, a schedule of two visits per week to each new nest was set up. Each new nest was classified as to species, stage of the nesting process (i.e., number of eggs, number and age of young), nest location, and habitat type. At each revisit, the stage of nesting and presence or absence of adult birds at the nest were recorded. Any unusual or abnormal phenomena or occurrences seen were noted.

After experience had indicated which vegetation subtypes on each area contained the greatest nesting densities of the bird species to be studied, searches for new nests were mostly restricted to those kinds of habitat (Figures 4 and 5). Searches were generally made during nest-check tours. In addition to the semiweekly searches associated with nest-checks, new areas were investigated for bird nesting throughout the study as time permitted. New areas were explored to a much greater extent on the test area, where relatively low nesting densities made extensive searching effort imperative as the study progressed.

Bird Species Studied.--Mourning doves, mockingbirds, cardinals, and scissor-tailed flycatchers were originally chosen as the principal species for study on the two areas. In May it became evident that the scissor-tailed flycatchers would not begin nesting soon enough, so lark sparrows were used instead of the flycatchers. An effort was made to find 100 mourning dove nests on each area, and to find as many nests of the other three species as possible.

All bird nests found that contained eggs or young were followed to termination, regardless of species. Records were kept of hatching dates, and of approximate fledging dates for each nesting effort that produced young.

Nest Examination Techniques.--Twice a week I examined the contents of each nest with the aid of a small mirror affixed to the end of an extendable bamboo pole (Figure 6). Notation was made of presence or absence of the adult bird on the nest, number of eggs in the nest and number and estimated age of young. Age of young doves was estimated by comparison to a pictorial chart provided by Hanson and Kossack (1963). Age of young of other species was approximated by experience gained during the study.

Causes of interruptions in normal egg and young development (predation, windblow, starvation) could usually be substantiated by careful investigation of the immediate premises. Adult bird feathers in profusion on or beneath the nest normally indicated predation on the adult (Figure 7). Nest disarrangement coupled with missing eggs or young was apparently predation. Eggs smashed on the ground from a nest in an unstable position usually meant loss from windblow. In cases where less evidence was available for interpretation, a subjective judgement based on experience was made.

As soon as a nest became empty, the development of that particular clutch of eggs was considered terminated. Any new nesting activity in the same nest was called a different nest.

A conscious effort was made to duplicate nest examination procedures as nearly as possible from the test to the control area, to prevent differences in nest development by dissimilarity in treatment.

Bird Call-Count Census.—A standard 20-mile bird call-count route was established near each study area (Figures 1 & 2) and was run about twice a month. Along these routes, driven by auto, a three-minute listening stop was made each mile, beginning thirty minutes before sunrise and ending one and a half hours after sunrise. During each three-minute listening period, the numbers of mourning doves and of bobwhite quail heard calling were tabulated. Only calling male birds were counted.

These routes were not run in cloudy, rainy, or windy weather in order that variability in calling activity would be affected as little as possible by the vagaries of weather. Results from the bird-call routes on the test and control areas were compared.

Analysis of Clutch and Brood Development

From data collected at repeated visits to nests, comparisons of the following elements of the reproductive processes of birds on the two study areas were made:

(a) clutch size

(b) peak of nesting activity

(c) eggs that failed to hatch in the normal incubation time

(d) percentage of eggs that hatched

(e) percentage of nests that hatched at least one egg

(f) percentage of eggs that eventuated in fledged young

(g) causes of mortalities in eggs and young

The ultimate purpose of these comparisons was to try to discover whether bird reproduction and survival on the test area was being altered by a factor or factors not impinging upon the bird populations of the control area, factors possibly attributable to sonic boom disturbance. With this importance of mortality causes in mind, an attempt was made to categorize the fate of each egg in nests under observation.

## RESULTS AND DISCUSSION

### Sonic Boom Disturbance

The occurrences of booms produced by overflights of supersonic aircraft in the vicinity of the test area are shown in Table 1. These booms produced a pressure change at ground level of approximately 1 pound per square foot or more, and were monitored at the detector stations on the Glen Rose Post Office Building and on the Bar L Ranch. All bird nests followed to completion on the test area were exposed to these pressure changes.

Five sonic boom detectors were installed on the control area the first week in April, and thereafter were checked twice a week. For about three weeks following initial installation of the detectors, considerable difficulty was experienced in keeping them in operating condition. Heavy and persistent rains caused moisture collection on the inside of the detector box, with concomitant malfunctioning of parts. Exposure of the red flag indicating that the device had been "pressure-tripped" was often the only obvious symptom of an inoperative condition, posing a problem in interpreting the meaning of a "tripped" detector.

However, in spite of continual maintenance problems in late April, usually two or three detectors were in operation at all tires. One exception was during the period April 23 to April 26, when only one detector was in operation, and it had been tripped sometime during that period.

During May and June, most of the three or four detectors on the control area functioned properly; and if one or two were tripped, it could usually be attributed to a thunderstorm occurring on the area. During the time interval May 24 - May 27, all four detectors in operation were tripped, and from May 31 to June 4, three of four were tripped. Heavy thunderstorms had occurred during each of those time intervals, on the control area. However, a local resident reported that he had heard a sonic boom approximately concurrent with the May 24 - May 27 period.

In summary, malfunct' ning of sonic boom detectors on the control area plus their response ɔ other than sonic boom disturbance limited their usefulness for yielding absolute information on occurrence on non-occurrence of booms. But they were functional enough to indicate that, if there was sonic-boom disturbance in the area, it was minimal and probably could be disregarded in the final analysis.

Inter-Area Comparisons of Reproduction and Growth

Data pertaining to reproductive success and early growth of young on the two study areas were analyzed from a comparative standpoint. Each parameter measured was in essence an attempt to discern differences between the two bird populations, differences that might in some way have been caused by impinging sonic booms on the one area and lack of booms on the other.

Relative Nesting Densities of Four Bird Species.--Densities of nesting birds on the study areas were assumed to be roughly correlated with man-hours of search time per nest discovered. Table 2 indicates the number of new nests found each week of the four principal species nesting on the test and control areas. An index to relative nesting densities, and thus of habitat quality, for each of the four species, was nests found per hour of search. For the entire study period, April 1st to mid-June, those ratios appear as in Table 2.

As will be seen later, the beginning of nesting of each of these species on the test site lagged behind that on the control site a week or more. For this reason, comparative "quality" of habitat was probably higher on the test site than that indicated by the figures presented in Table 2. Nevertheless, the relative unsuitability of the test site for mourning doves, and its greater attractiveness to cardinals was very obvious during field work.

Reasons for such a paucity of mourning dove nests on the test site were not absolutely clear. However, doves apparently preferred to nest on horizontal branches of medium-sized live oak trees in savanna situations (Figure 8), and in cedar elms by second choice, and this "preferred" type vegetation was more abundant and widely distributed on the control area. The greater abundance of cardinals on the test site was probably correlated with the availability there of more densely wooded areas.

Ultimate Fate of Eggs of Four Bird Species.--As eggs and nestlings disappeared from nests, the fate of each egg or young bird was categorized on the basis of available evidence. Table 4 segregates eggs by species and destiny. Test and control area categories are paired for ready comparison. A number of these parameters are tested statistically for differences later in this section.

Hatching and Nesting Success

All active bird nests discovered on the study areas were followed to termination. Table 5 shows nests followed to completion and percent that hatched one or more eggs. As can be seen from this table, only one species was found that was not common to both areas--a black-chinned hummingbird nest on the test site. This similarity in species make-up suggested that (1) the habitat types on the test and control areas were quite similar in respect to use by nesting birds, as had been theorized early in the study on the basis of a quick field appraisal, and (2) none of the principal nesting species were excluded from either area because of differences in other environmental factors (i.e., sonic boom). Numbers of nests found of most species were too small to indicate which area supported a higher density of a particular species.

Table 6 shows that large percentages (77.5% to 96.6%) of bird eggs which were brooded for the normal incubation period hatched. Chi-square tests for differences in hatching rates between the test and control area eggs revealed no differences within species (Table 7). Thus, sonic boom disturbance apparently had little or no effect on hatchability of eggs on the test area.

Percent of nests that hatched at least one egg was arbitrarily chosen as a measure of nesting "success" by species for each study area. Figure 9 graphically demonstrates that nesting success for mourning doves and mockingbirds was seemingly greater on the control area than on the test area (58.7% vs. 38.7% for doves and 63.3% vs. 33.3% for mockingbirds). Table 8 lists success by percentage. Chi-square tests for differences show that nesting success for mourning doves was indeed greater on the control than on the test site, with 95 percent confidence, but indicated no difference in successes by mockingbirds, cardinals, or lark sparrows at this level of probability (Table 9). As will be seen later, predation upon eggs was the principal apparent factor contributing to the greater nesting failure on the test area by doves and mockingbirds. I could find no evidence to link this difference in nesting success with sonic boom disturbance.

Production of Young

Less than half of the eggs laid by any species eventually produced fledgings, that is, young birds that flew from the nest. Figure 10 shows fledging rates as percentages of total eggs followed to termination. The four principal species are compared.

Table 10 tabulates numbers of fledgings by species, and lists the percentages shown graphically in the preceding table. Chi-square tests for differences in proportions of eggs eventuating in fledged young (Table 11) indicate that mockingbirds showed higher fledging production on the control area than on the test area (39.1% vs. 14.5%). No difference (at 95 percent probability) between areas could be detected for the other birds. Table 4 indicates that a greater effect of predation on the test area might have been a principal factor in the low fledging rate of test mockingbirds. And indeed, in the following section, predation is shown to have a significantly greater impact on the test area over the control area for mockingbirds.

## Effects of Predation

Predation was the major cause of egg and nestling mortality on all bird spcies studied. Loss of eggs or young from the nest were the most common results of predator activity, but not uncommonly adult birds were taken from the nest by predators.

Table 12 gives total losses by predation for four bird species on the test and control areas. As indicated before, mockingbirds suffered a significantly greater predation-caused mortality on the test area than on the control area (65.8% vs. 44.3%, respectively). Chi-square tests (Table 13) bear this out. Reasons for the higher test-area predation rate were not evident. Mourning doves, cardinals, and lark sparrows showed rather similar rates of predation loss from both areas.

Clutch Sizes of Three Bird Species.--The number of eggs laid per nest, or clutch size, is an important factor in the reproductive success of a bird population. Environmental factors may have marked effect on the number of eggs laid by birds having a variable clutch size, and thus upon total reproductive success of a species.

Figure 11 compares clutch sizes of mockingbirds, cardinals, and lark sparrows on the test area and on the control area. (Mourning doves were omitted from this comparison since they have a genetically-determined clutch size of two, and seldom deviate from this number regardless of other factors.) Mean clutch size was not found to be significantly different between test and control populations for any of the three species tested. Table 14 gives clutch sizes by study area and species, and t-values of nests for differences. Occurrence of sonic booms on the test area had no discernable effect upon number of eggs laid by nesting birds.

Temporal Nesting Activity of Four Bird Species.--Intensity of nesting activity was gauged by the number of new nests found per hour of search each week. By plotting nests-per-hour from week to week, a diagram of nesting activity throughout the spring was constructed (Figure 12). Examination of these graphs shows that initiation of nesting on the test area lagged about a week behind that on the control area for mockingbirds, cardinals, and lark sparrows, and two weeks or more behind for mourning doves. The peak of nesting activity on the test area was delayed even more--two to three weeks later than the apparent peak on the control area.

Reasons for the nesting delay on the test area were not clear. Some observed differences that might have affected initiation of nesting are:

(1) The test area was thirty miles to the north of and at a slightly greater elevation than the control area.

(2) Tree species used for nesting (particularly live oaks and cedar elms) acquired new leaves later in the spring on the test site than on the control site.

Calling Activity of Doves and Quail.--Calling intensity by male birds of a species frequently indicates physiological readiness for breeding. In mourning doves and bobwhite quail, considerably research has been done on the breeding activity of birds as reflected in males heard calling along a 20-mile survey route.

There is a seasonal cycle in dove cooing, beginning in early spring and usually reaching a peak in late spring or early summer. Most investigators have found that peak nesting and peak cooing of doves occur at about the same time (Frankel and Baskett 1961; Mackey 1965). Calling activity by bobwhite males begins in mid-spring before actual breeding begins. The bulk of bobwhite whistling is carried on by unmated males (Elder 1956). With the onset of pair formation and nesting, calling decreases in intensity.

Figure 13 compares calling activity of male mourning doves in the vicinity of the test area and near the control area. From early March to Mid-June there was considerable fluctuation from one survey time to the next on both areas, but no marked trends on either area. More birds were heard on the average per stop on the control area route than on the test area route (4.33 vs. 2.71), respectively). Again, this difference was probably caused by better habitat quality of the control area for mourning doves, and agrees with comparative results of nests found per hour on the two areas (Table 3). The large number of doves heard in early spring relative to nesting activity at that time was likely due to calling by transient migrants on the areas.

Numbers of quail heard calling along these same routes are depicted in Figure 14. Trends as well as average numbers of birds heard per stop are almost identical between the test and control routes. The control area route averaged 2.60 birds heard per stop after commencement of calling activity, and 2.76 birds were heard per stop on the test area route. Calling activity increased rapidly from early April and peaked in early June on both areas. This indicates that the temporal changes in physiological breeding condition, and the pair formation in quail were the same on the two areas.

In summary, comparisons of physiological breeding condition and of breeding activity in males among doves and quail as evidenced by calling activity appeared quite similar on both the test and control areas. Sonic boom disturbance on the test area did not appear to adversely affect these phases of the reproductive cycle in the two species compared.

## SUMMARY AND EVALUATION

Two sites were selected to study reproduction of wild birds and early survival of their young as possibly influenced by recurrent sonic boom disturbance. A test area, located near the flight path of supersonic aircraft passing near Glen Rose, Texas and a control area free from "boom" disturbance, about 30 miles south of the flight path, were used for study of nesting birds. Sonic boom detectors were maintained near the test and control area to monitor pressure changes incident upon the areas.

The following parameters of reproduction and survival of young were compared between areas for mourning doves, mockingbirds, cardinals and lark sparrows:

(1) nesting density

(2) hatching and nesting success

(3) production of fledgings

(4) effects of predation

(5) clutch sizes

(6) breeding activity as evidenced by calling behavior

Of 301 nests followed to termination on the two areas, 193 were mourning dove nests, 54 were mockingbird, 29 were cardinal and 25 belonged to lark sparrows. Statistical tests for differences in the above listed characteristics showed some dissimilarities between the two areas, particularly in nesting density, nesting success, and production of young in mourning doves and/or mockingbirds.

Analyses of comparison between the test and control area indicated that:

(1) The test area was inferior habitat for mourning doves and mockingbirds as compared to the control area. Cardinals, a species preferring wooded areas, did well on the test area.

(2) Nests found indicated that the species composition of nesting birds was very similar between the two areas.

(3) Hatching rates of eggs were not different between the test and control areas.

(4) Nesting success (percent of nests hatching at least one egg) for mourning doves was significantly greater on the control area. This difference was largely due to a greater incidence of egg predation on the test area. No difference was found for other species.

(5) A greater percent of mockingbird eggs produced fledgings on the control area than on the test area, apparently because of more predator pressure on eggs and young on the test area. Other species showed no difference.

(6) Average clutch size was found to be not significantly different between the test and control areas for any species.

(7) The beginning of nesting of birds on the test area lagged behind that on the control area one or two weeks, and nesting peaks were similarly delayed. Reasons for the delay were possibly naturally occurring environmental differences.

(8) Spring calling activity by males of mourning doves and bobwhite quail showed essentially the same trend on both areas. Fewer mourning doves were heard calling in the vicinity of the test area, as

expected, since the control area was apparently better habitat than the test area.

Some of the differences in production and survival of birds between test and control populations were probably caused by habitat differences. Complete explanations for all dissimilarities could not be made; however, I could find no indication that sonic booms impinging upon the test area birds affected their nesting cycle.

## SECTION II. LABORATORY STUDIES

# EFFECTS OF PRESSURE ON REPRODUCTION AND GROWTH OF BOBWHITE QUAIL

Conducted by

Dr. James G. Teer

March 1, through August 15, 1973

## INTRODUCTION

Studies were conducted between March 1 and August 15, 1973 to determine the effects of pressure similar to that delivered by aircraft flying at supersonic speeds on bobwhite quail (Colinus virginianus). These studies were designed specifically to identify and measure alterations or changes in two basic biological processes--reproduction and growth--in the life cycles of a common bird having widespread interest and distribution in the United States.

The bobwhite quail was used in the experiments because of its popularity as a game bird, its adaptability to pen and cage studies, and the ready availability of eggs from commercial game bird breeders. In addition, the egg of the bobwhite quail is typical of the eggs of members of the Order Galliformes which includes most of the game birds in the United States and domestic poultry. The quails, pheasants, grouse, and domestic poultry are members of the order, and except for waterfowl (Order Anseriformes) and pigeons and doves (Order Columbiformes), the Order Galliformes contains most of the birds used in sport hunting and raised for the table.

The research program included three major phases:

1. Measurement of hatching success of eggs of bobwhite quail subjected to three pressures delivered daily at three frequencies during the first 18 days of incubation,

2. Determination of growth patterns of young bobwhite quail hatched from eggs subjected to pressure treatments, and

3. Determination of survival patterns of young bobwhite quail hatched from eggs subjected to pressure treatments.

The hypothesis under which these experiments were conducted was simply that pressures above normal standard atmospheric pressures would decrease hatching success, reduce growth rates, and increase mortality of young chicks from residual effects of the pressure treatments on the eggs during incubation.

## EQUIPMENT, PROCEDURES, AND QUALITY CONTROL

Four cabinet electric incubators equipped with thermostatic controls were used to incubate the eggs. The four incubators had a total of 30 trays. Each tray was capable of holding about 300 eggs without crowding of the eggs or the chicks when hatched. The incubators were set up and the temperature regulators were calibrated to maintain a constant temperature of 99.75°F. Moisture pans were kept full of water to humidify the incubators; wet bulb thermometer readings were kept in the upper 80's. The incubators were fumigated with potassium permanganate and formaldehyde before the eggs were set.

An apparatus designed to simulate the pressures of aircraft flying at supersonic speeds was supplied by the Federal Aviation Administration. The particular apparatus was the same as used by Rucker (1973) in his studies of the effects of sonic boom on hatching of salmonid fishes. Characteristics and operations procedures of this apparatus were tested and described by Tensor Industries, Inc. (1973). The sonic boom simulator was calibrated with an oscilloscope both before and at the end of the 18-day experiments. These tests showed that there were no changes in pressures delivered by the apparatus at the various dial settings throughout the study, and the pressures delivered by the apparatus were correct.

A STATOS - I recorder was also provided by the Federal Aviation Administration and was to have been used in recording the pressures in each experimental regime; however, this equipment was inoperative throughout the experiments due to a malfunction in the pump and/or electrostatic process for depositing a toner solution on the paper to display the recorded impulses. The use of the oscilloscope in maintaining quality control in the experiments was deemed successful.

The sound chamber and control unit were placed alongside the incubators on a sturdy table. The incubator trays were taken from the incubators and placed one at a time in the sound chamber. The pressure appropriate to the experiment was delivered. The trays were then returned to the incubator in a rotational pattern to vary every tray's position in the incubators at least one time per day. This pattern was maintained throughout the study to mitigate the effects of position in the incubators on hatching success.

Eggs in each tray were turned once each day by gently rolling them with the flattened palm of the hand. This procedure is necessary to prevent the allantoic and amniotic membranes from adhering to the shell. All eggs in all trays were handled in such manner to maintain uniformity of treatment. Care was taken in handling the trays when passing them from the incubators to the sound chamber and back again to prevent shocks and jolts.

An egg candler was constructed to test viability and development of the eggs. This candler consisted of a small box, a cube of about 10 inches on the side, fitted with a small opening to a light source in the box. A 40-watt bulb was placed in the box and eggs were placed on the velvet-lined apparatus to test developing embryos and/or infertile eggs.

Holding pens (Fig. 15) and devices for caring for the hatchlings and young birds were conventional gear used in most game bird breeding and propagation programs. Heat lamps and brooders were essential during early life of the birds because hatching of birds occurred in the first week of April. This month is a cool month in central Texas, and some very seasonable weather occurred shortly after the birds were taken from the incubators.

Additional information on experimental design and procedures is given with each experiment.

## RESULTS AND DISCUSSION

### Hatching Success of Bobwhite Quail

As explained above, this experiment was conducted with the hypothesis that hatching success of bobwhite quail eggs is reduced as pressures are increased and as the frequency of application of the pressures is increased.

Nine thousand eggs of the eastern race of the bobwhite quail were purchased from a commercial game breeder--Manchester Farms, 733 Reynolds Road, Sumter, South Carolina 29150. The eggs were shipped air-freight in styrafoam chests. Fresh eggs from adult layers were requested from Manchester Farms. On arrival, the eggs were selected for incubation by examining each egg for size, shape, cracks, or striations in inner membranes suggesting breaks. Uniform, unblemished eggs were selected for the experiments.

A total of 7,425 eggs were placed in 30 trays in the four incubators (Table 15). The experiment was designed for pressures of 2.0, 4.0, and 5.5 pounds per square foot (PSF) to be delivered once, twice, and three times per day. Each treatment regime had three replicates; one set of three replicates were not treated. The treatments were begun on the first day of incubation and terminated on the eighteenth day. Thus those eggs treated three times a day received a total of 54 treatments; those twice a day received 36 treatments; and those once a day received 18 treatments.

Every replicate in every treatment regime had 250 eggs per replicate except the three replicates treated with 5.5 PSF of pressure once per day. These replicates contained 225 eggs because sufficient numbers of good eggs were not available to fill out the replicates to 250 each.

At the end of the eighth day of incubation, the eggs were candled to remove infertile eggs and those that showed positive evidence of dead embryos. In the later cases, the embryonic material was not organized and without a clear eye spot. Often, a circular smear of blood or a semilunar-shaped yolk deposit was adhered to egg shell. These deposits would not move as the egg was turned. Every egg in the experiment was candled and only the developing ones were retained to continue incubation.

To keep the young quail in the tray in which they were hatched, a fine guaze netting was stapled over the tops of the trays on the 19th day of incubation (Fig. 16). At hatching the birds were counted and removed from the trays and placed in cardboard cartons to transport them to the brooder pens. All capped eggs (evidence of hatching) were counted and each remaining egg was examined to determine if the embryo had developed and died in the shell.

Eighth Day of Incubation

Of the 7,425 eggs starting incubation and subjected to the various treatments of pressure regimes, 6,380 eggs were still viable and developing at the end of the eighth day of incubation (Table 16). These developing eggs represented a survival rate of 85.9 percent of the total set; individual treatment results ranged from 82.9 to 87.9 percent.

A factorial analysis of variance was conducted to test for differences in survival of the eggs (Table 17). In this analysis tests were made among the treatment results, and all treatment results were contrasted with the control. There were no statistical differences in treatment results; however, a statistically significant difference ($p = 0.05$) was found between the control group and the treated groups.

Nonetheless, when the percentage of survival of the eggs of the control group is compared with the overall survival of the eggs that were treated, it is seen that the control group had a smaller survival (82.9 versus 86.3 percent). It is clear from this comparison that the treatments did not reduce the survival of embryos to the ninth day of incubation.

There is no reason to suspect that the treatments destroyed the embryos or arrested their development. It is likely that many of the eggs were not fertilized because eggs were obtained from quail during the very first egg-laying stages in the spring season. It is surmised that some of the birds were not paired at the beginning of egg laying. Moreover, some eggs invariably are infertile despite the stage of the egg-laying cycle.

## Hatching Success

As explained in the methods section, some of the treatment samples--namely those involved in the 2.0 PSF of pressure experiments--were adjusted to have a uniform set of eggs at the beginning of the ninth day of incubation. Thus at the beginning of this stage of the experiment, the total sample contained 6,331 viable eggs (Table 18). These eggs were carried through to hatching which occurred on the 21st through the 23rd day of incubation.

Hatching success was measured and expressed as a percentage of the total number of eggs set on the ninth day of incubation. The total set of 6,331 eggs produced 5,048 chicks which were removed alive from the incubator trays (Table 19). These chicks represented an overall hatching success of 79.7 percent. This figure is low according to normally achieved hatching percentages attained in r d-season; however, it is in general agreement with hatching success attained in early season sets.

Hatching success of the control group was 76.8 percent, a lower percentage than that of any of the treatments. A factorial analysis of variance was conducted to test for differences between the treatments and the control and between each of the treatments of pressure and frequency of application (Table 20). These tests showed significant differences between the results obtained from the various frequencies ($p = 0.01$) and also between the results obtained from the various pressures ($p = 0.05$). The control results were not different from treatment results.

In interpreting these differences, the data were examined for uniformity in trends of effects (Fig. 17). The most frequently applied pressures (three times per day for 18 consecutive days) resulted in the highest hatching success, and the intermediate pressure regime (4.0 PSF) resulted in the highest hatching success of any of the treatments. Trends were not constant in one direction.

Thus, while there is statistical differences at a high level of probability, the hypothesis that pressure decreases hatching success has not currency or biological verity.

## Growth Rates of Bobwhite Quail

The hypothesis that pressure in excess of standard atmospheric pressure on incubating eggs would alter growth patterns of the bobwhite quail though some residual effect was tested by following the weights of the birds from each treatment group through twelve weeks of age. A sample of birds was weighed soon after they had hatched and dried, and, without exception, the birds from each treatment set averaged eight grams. At the end of the first week of life and at weekly intervals thereafter, a sample of 25 birds was randomly caught from each of the ten groups and weighed on a spring balance. Weights were taken in grams and the data presented in Table 21 are means of each sample of 25 birds rounded off to the nearest gram.

The means of the weights through the first eight weeks of life were tested for differences with a factorial analysis of variance in which all elements of the treatment regimes (pressures, frequency, and weeks) were separated out (Table 22). The control group was tested against all treatment sets. Highly significant differences ($p = 0.01$) were found for practically all tests including pressures, frequencies, weeks, and interactions.

However, with these data also, when one examines the trends of the gains that went into the analysis, it is apparent that gains varied up and down between groups without any definite trend for any treatment set. The variability was due to an outbreak of enteritis which started within a month after hatching. Birds with the disease stopped eating and losses of weight followed. It seemed that as soon as medication arrested the problem in one group, it broke out in another experiment set. All groups were affected at one time or another, and the experimental results were confounded very badly by the disease.

By the ninth week, the disease had affected all of the groups of birds; therefore, the analysis of variance tests were not extended beyond eight weeks. Heavy medication was begun and the birds were moved from their pens and put into new facilities where the disease had not occurred. They were combined into four groups according to pressures in the treatment regimes. After a few days they began to show improvement. At the end of twelve weeks, only a few grams separated the weights of the birds in the four groups (Table 24).

While this experiment is not as clean as desired, I could not find any real evidence to suggest changes in growth patterns of birds hatched from eggs that had been subjected to inordinate pressures. Enteritis is a common disease of game birds and can be expected in any group of birds raised in close confinement. There is no evidence to show that pressure applied to the eggs predisposed the disease in the hatchlings.

## Mortality and Survival

Losses of birds in each of the four treatment groups were counted and recorded each week through the eighth week of life to test the hypothesis that pressures similar to those delivered by supersonic aircraft on incubating eggs of bobwhite quail had a residual effect on mortality of the hatchlings. These data were assembled and life tables were constructed for each of the groups of birds in the four teatment regimes, these being the 2.0 PSF, 4.0 PSF, 5.5 PSF, and control groups (Table 24). Such calculations as are made in life tables give ready comparative data for vital statistics of populations, and it is not necessary for our comparisons that assumptions underlying the calculations for wild populations be met. That is to say, such assumptions that there are no differences in recuitment, and that the population is a stable population need not be made for birds with a finite number in penned conditions. The life table calculations simply relate to the birds in the penned population during the eight weeks study of their mortality and survival rates.

In these tables, which are calculated from deaths in the populations, the data are transformed to 1,000 members. This transformation is customarily done by demographers to express mortality ($q_x$), further expectation of life ($e_x$), and survivorship ($l_x$) in terms of 1,000 animals. The age interval of time (x) used in the calculations was two weeks; thus the estimates of further expectation of life must be multiplied by two to arrive at the absolute value for each of the two-week intervals. In interpreting the data in Table 24, it is more important to compare mortality and further expectation of life of the four groups of birds than simply to relate these same estimates to some norm in pen-reared stocks or wild populations of galliform birds. The important point for our purposes is to see if there are differences in these estimates between the four groups, and the two vital parameters, mortality rates and further expectations of life, are further summarized in Tables 25 and 26.

It is quite apparent from the life table data in the summary tables that mortality rates for all but the 4.0 PSF treatment group were similar. The 4.0 PSF group was largely free of enteritis during the first few weeks of life and thus mortality was not as high as in the other groups.

Estimates of further expectation of life was virtually the same for each age interval in each group.

I concluded that pressures had no effects on mortality and survival of the hatchlings.

## SUMMARY AND EVALUATION

A total of 7,425 eggs of bobwhite quail were selected from 9,000 eggs purchased from a commercial dealer and placed in 30 trays in four incubators for hatching. Simulated sonic booms were delivered in three pressures and at three frequencies to 9 subsets containing three replicates of eggs. Another set of three replicates was not treated and was used as a control. The treatments were begun on the first day of incubation and were continued for 18 consecutive days. The experimental design was made to test the hypotheses that pressures similar to those delivered by aircraft flying at supersonic speeds would reduce hatching success, reduce the growth rate, and increase mortality of chicks hatched from eggs subjected to such pressures.

At the end of the eighth day of incubation, all eggs were candled to remove infertile eggs and those with dead embryos. Tests were made to determine if pressure treatments resulted in differences in mortality of eggs through the eighth day of incubation. The eggs were then followed to hatching on the 21st, 22nd, and 23rd days. Tests were made to determine if pressure treatments had effects on hatching success.

The birds were weighed weekly to determine growth patterns. Mortality rates were established by counting dead birds from each treatment group. Mortality was expressed and exhibited through the use of life tables.

Analyses of the experiments showed that:

(1) A total of 6,830 eggs were still viable and developing at the end of the eighth day of incubation. These eggs represented a survival rate of 85.9 percent and individual treatment survival rates ranged from 82.9 to 87.9 percent. A factorial analysis of variance showed no statistical difference in results or survival of any of the treatment groups.

(2) The experiment was continued with 6,331 eggs in the incubators. These eggs produced 5,048 chicks which were taken alive from the incubators. These chicks represented an overall hatching success of 79.7 percent which is in general agreement with hatching success of early season sets.

(3) There were significant differences at high levels of probability between hatching success of the control group and the treatment groups as well as significant differences between the hatching success of eggs subjected to various pressures and frequences of application of the pressures. However, when the data were plotted and examined for trends, there were no uniformity or linearity in direction of the hatching results. Some high pressures were associated with high hatching successes and some low frequencies were associated with high hatching successes. Thus, the hypothesis that pressure decreases hatching success was not accepted.

(4) Growth patterns of bobwhite quail hatched from eggs subjected to inordinate pressure regimes were established and tested for differences. There were some differences in weights of birds subjected to various pressure treatments at the same age. However, weights, like hatching

success, showed no uniformity in trends. Some high pressures and some frequencies of applications of the pressures were associated with higher weights than some of the lower pressures. An outbreak of enteritis in young birds had an effect on food ingestion and weight gains, and thus these experiments were not as clean as desired. Nonetheless, there was no evidence to suggest or support the hypothesis that pressures similar to those produced by supersonic aircraft affected weights of bobwhite quail. By the twelfth week of life, the birds were practically the same size with only a few grams separating their weights.

(5) Mortality rates were generally the same for each treatment group for each age through the first eight weeks of life, and the estimates of further expectation of life for all groups were very similar. There was no evidence to support the hypothesis that pressures on eggs had a residual effect on the hatchlings.

From these experiments, we concluded that pressures in the ranges (2.0 through 5.5 PSF) used in the treatments and at the frequencies at which they applied had no effects on the growth, reproduction and mortality of bobwhite quail.

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Texas Utilities Services, Inc., Fort Worth, Texas, kindly permitted us to use their property near Glen Rose for a study area. Mr. Bob Allen of the Texas Parks and Wildlife Department was very cooperative in providing access to the Dinosaur Valley State Park for use as an auxilliary study site. Mr. Tom Parks of Clifton, Texas provided access to his ranch which was used as the control area in the field studies. His cooperation is greatly appreciated.

Miss Beverly Hotard typed the manuscript and had it duplicated. Her diligence in sheparding the manuscript through all of its drafts and final typing was professional in every way.

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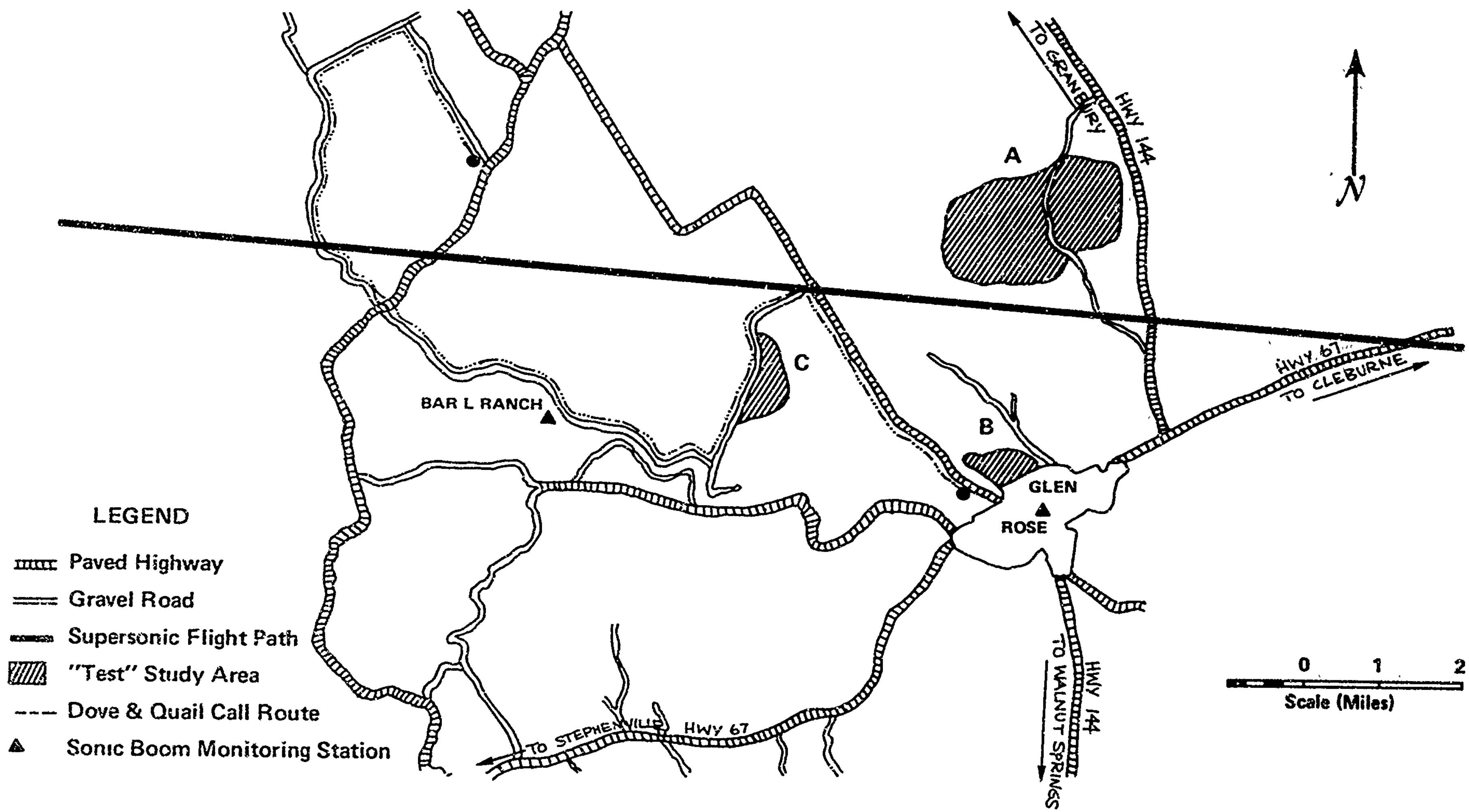


Figure 1. Locations of "test" study sites and dove-and-quail call-count route with respect to flight path of supersonic aircraft, Somervell County, Texas. Area A is Texas Utilities Services, Inc. property, Area B is the Glen Rose Golf Course, and Area C is the northern part of Dinosaur Valley State Park.

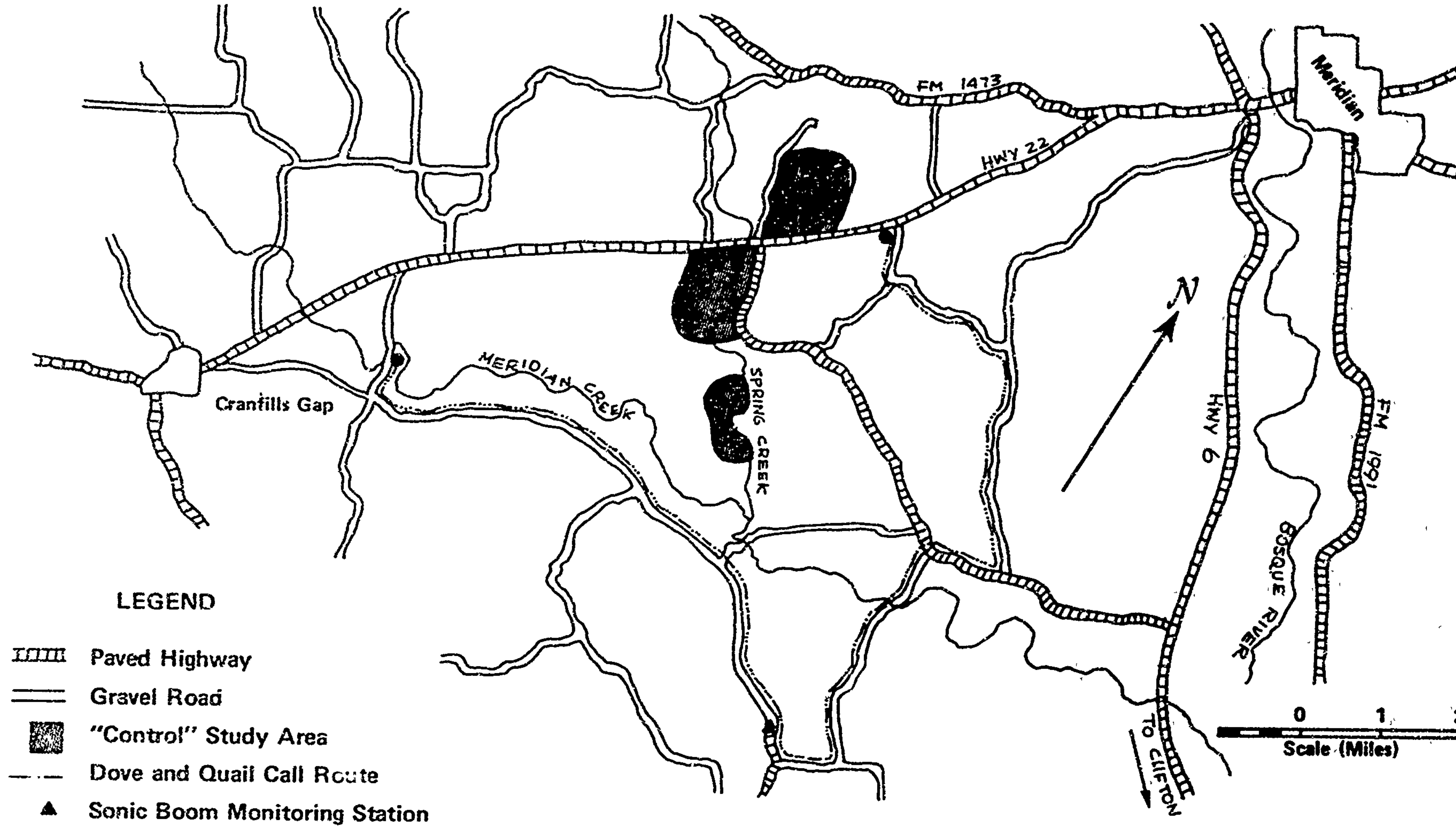


Figure 2. Location of the "control" study area and of the control dove-and-quail call count route in Bosque County, Texas.

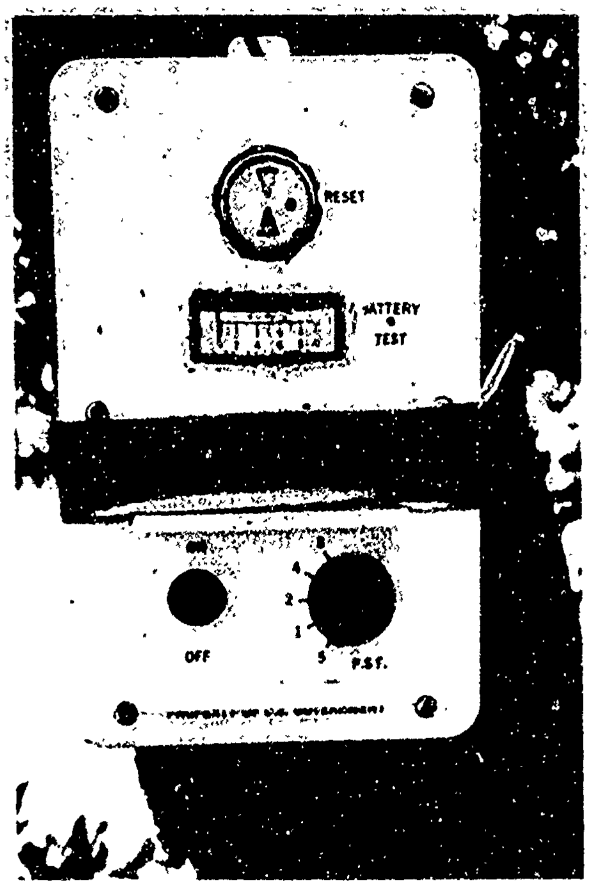


Figure 3. Telephonics sonic boom detectors (Model 529) were used to monitor sonic boom disturbance during the study.

Figure 4. Optimum habitat for dove, mockingbird, and lark sparrow nesting on the test area.



Figure 5. Optimum habitat for dove, mockingbird and lark sparrow nesting on the control area.

Figure 6. Examination of nest contents usually required the use of a mirror affixed to the end of an extensable bamboo pole.



Figure 7. Predation upon adult birds was usually evident from the presence of feathers in the immediate vicinity of the nest.

Figure 8. Mourning doves preferred horizontal limbs of medium-sized trees for nesting sites.

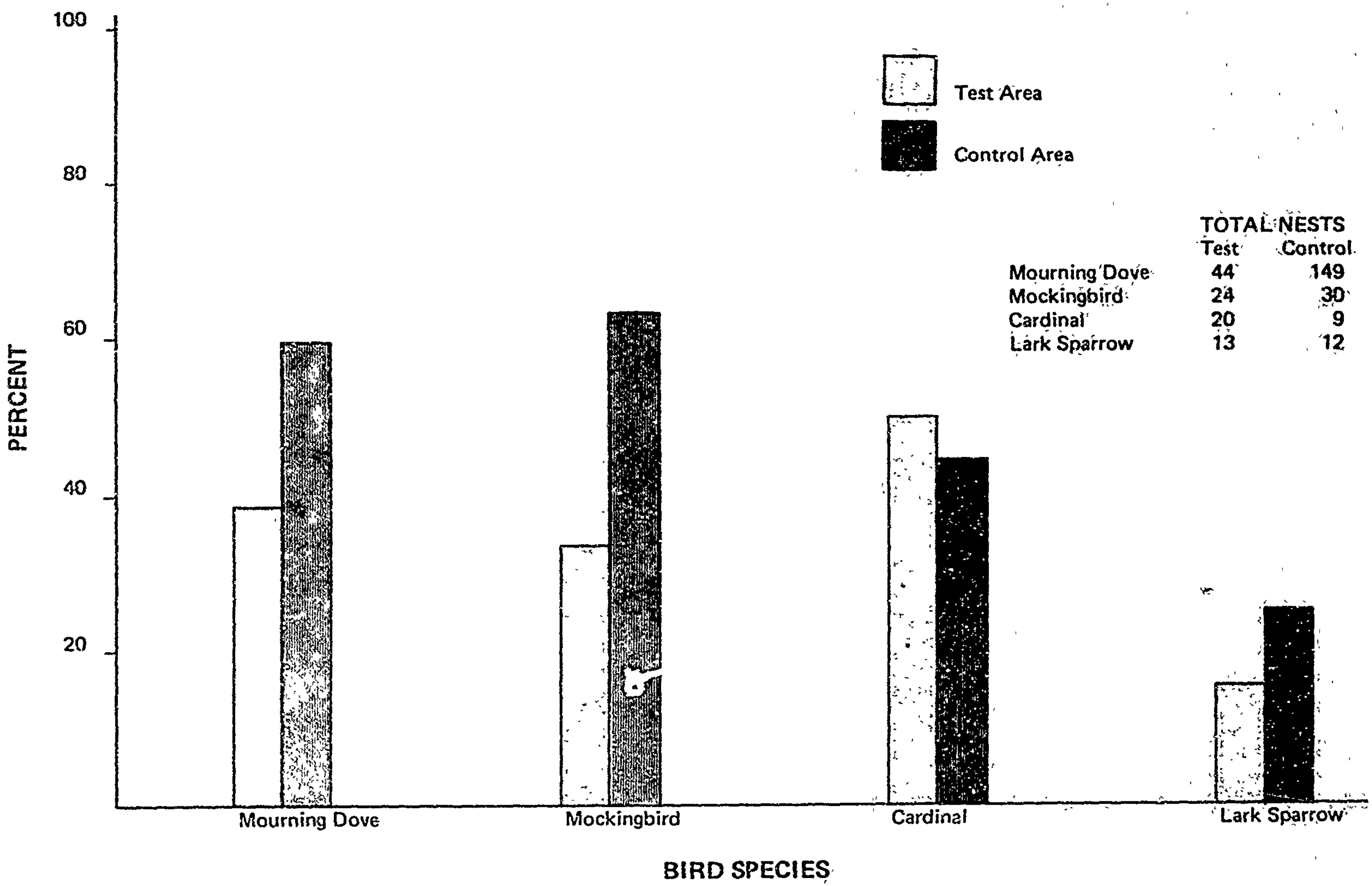


Figure 9. Percent of nests of four bird species on the test and control areas that hatched at least one egg.

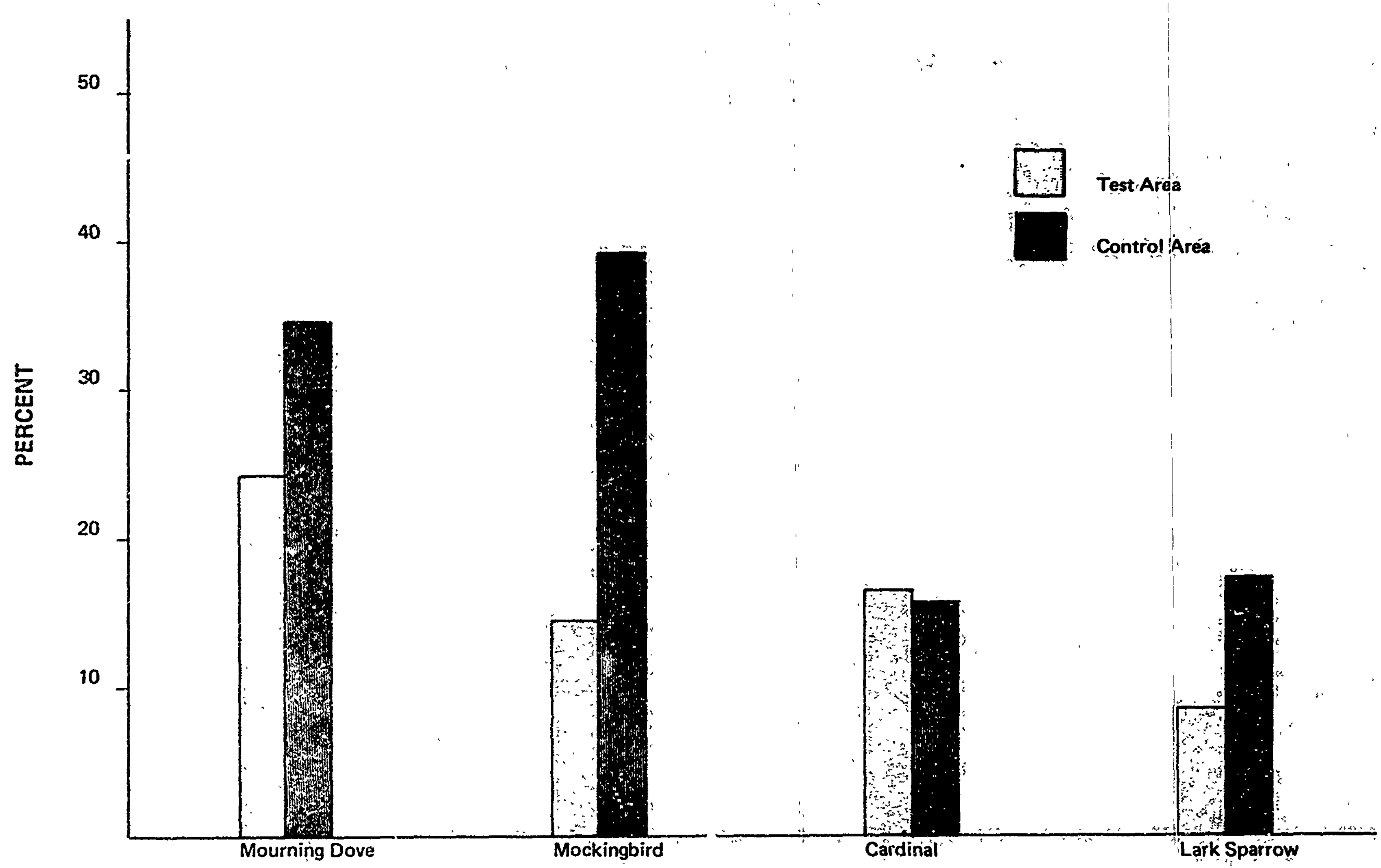


Figure 10. Percent of bird eggs of four species on the test area and control area that eventuated in fledged young.

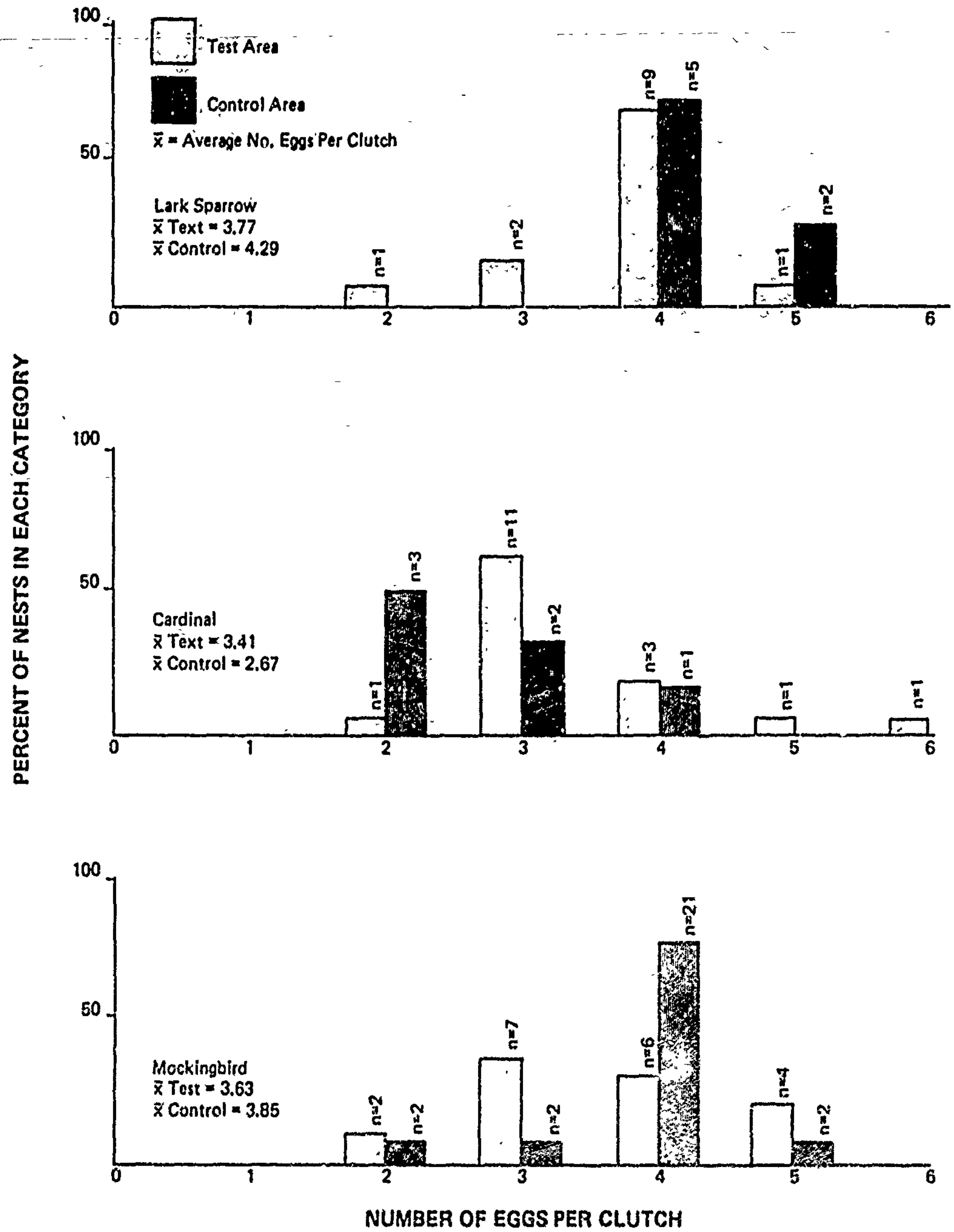


Figure 11. Comparisons of numbers of eggs per clutch for three bird species on the test area and control area.

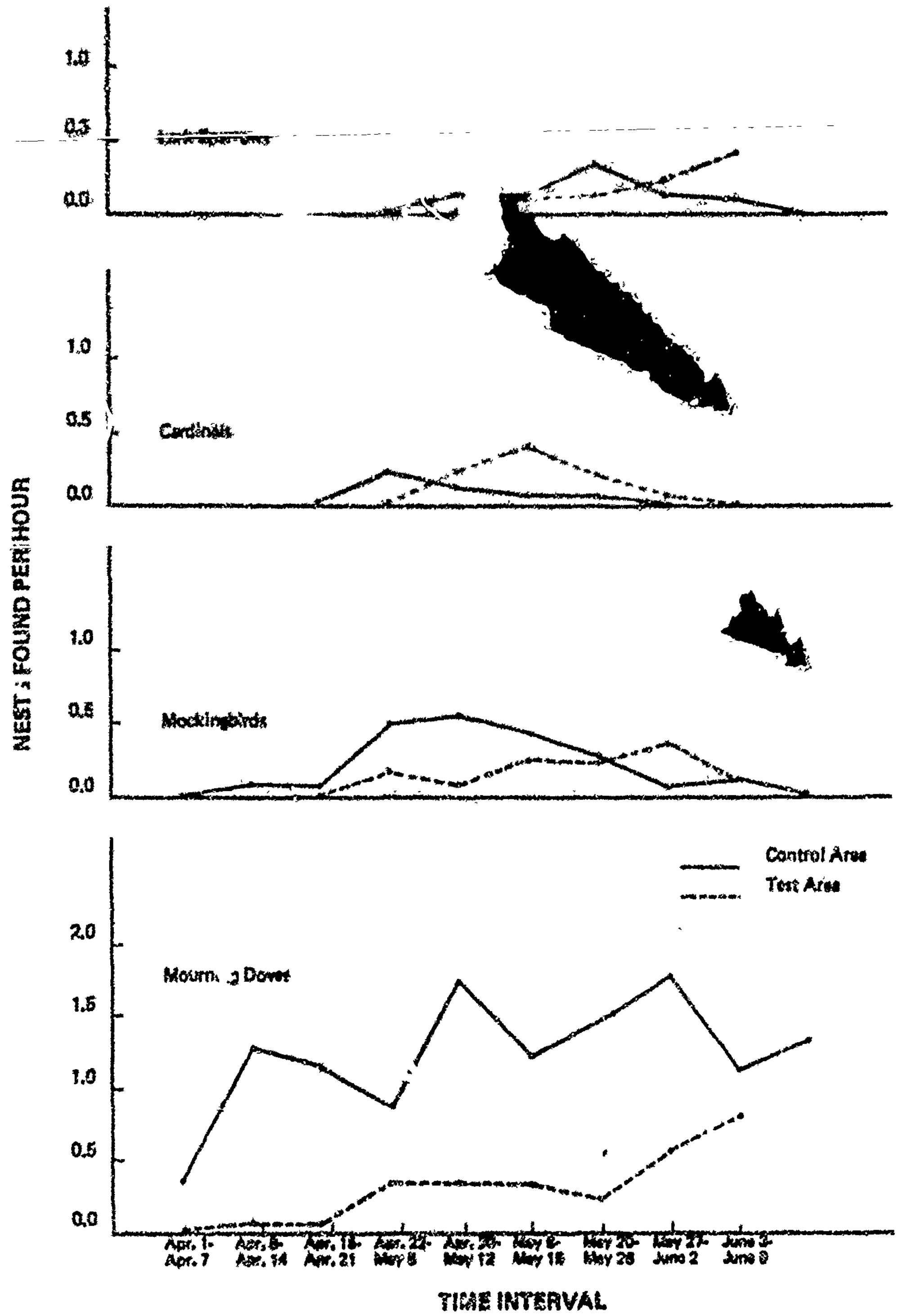


Figure 12. Weekly intensity of nest-building activity on the test area and ... as assessed by number of new nests found per hour of search.

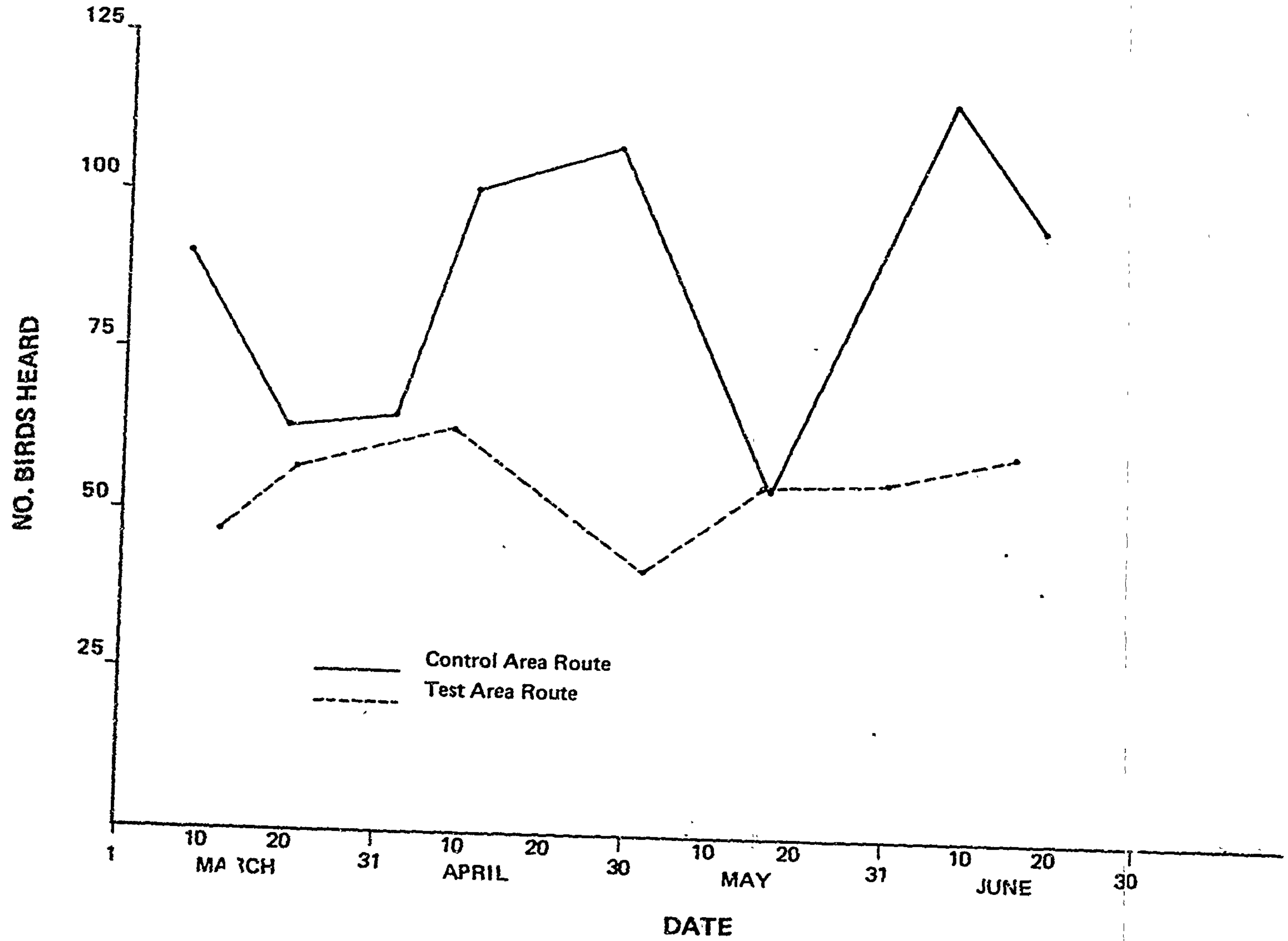


Figure 13. Numbers of doves heard calling per 20-mile call-count route during spring surveys near the test area and near the control area.

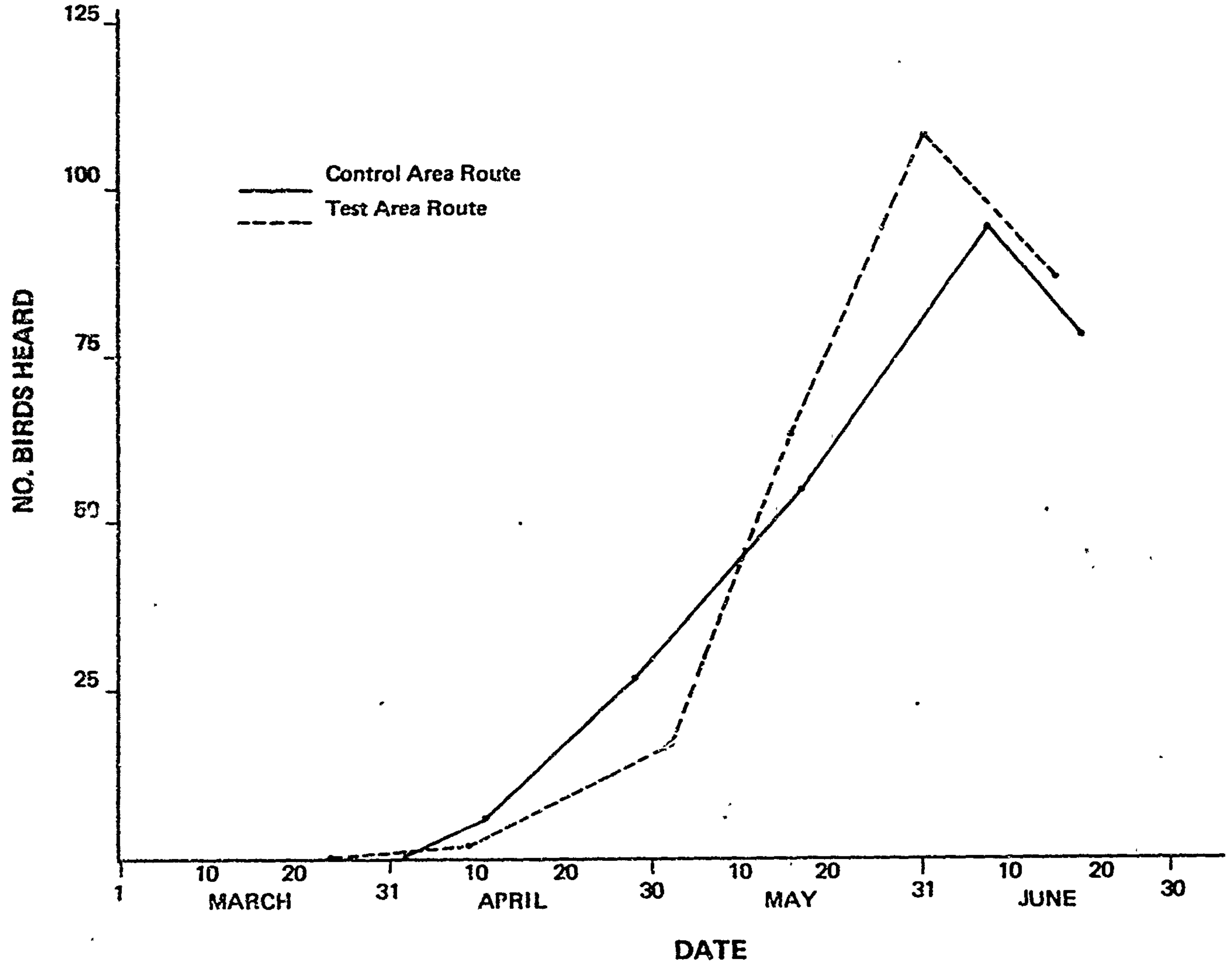


Figure 14. Numbers of quail heard calling per 20-mile call-count route during spring surveys near the test area and near the control area.

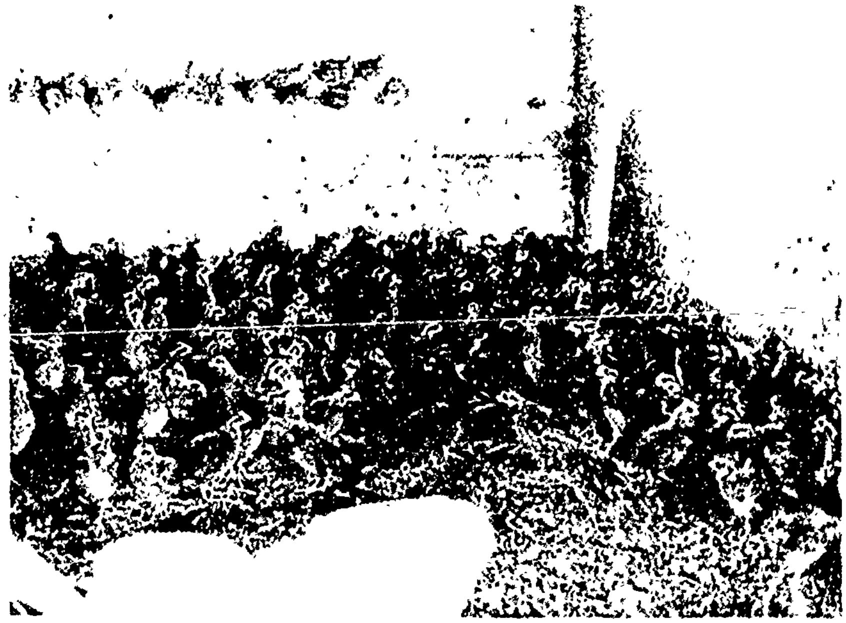

Figure 15. Nine-week old bobwhite quail in holding pens. Each treatment group was kept separate through the eighth week of life to follow growth rates and mortality.

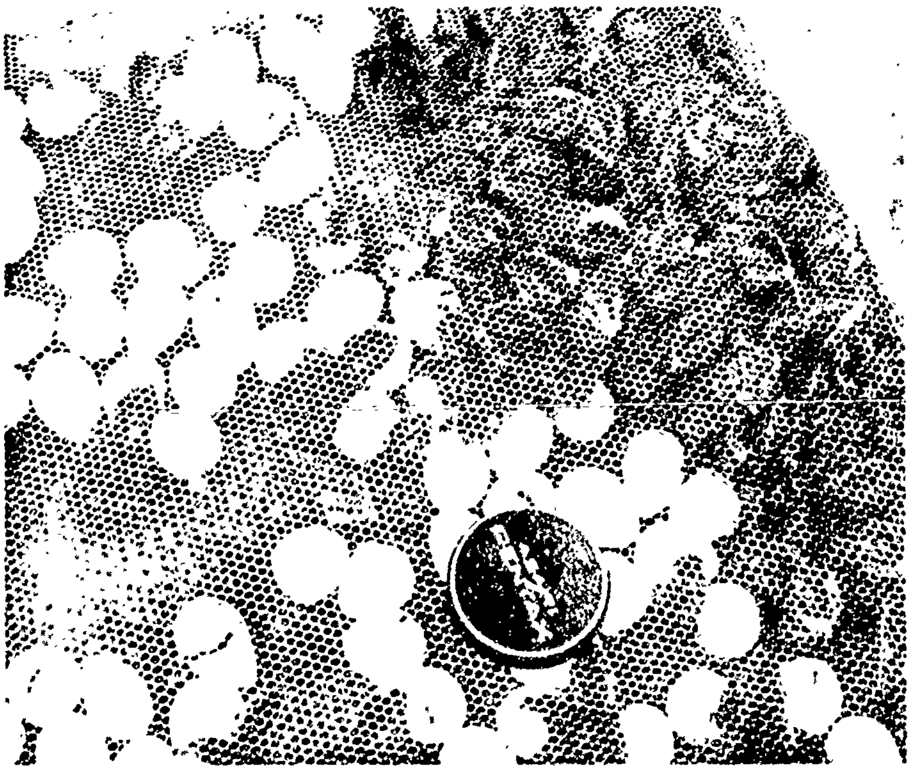

Figure 16. Fine cloth netting was stretched across incubator trays to keep newly hatched young from escaping. Counts of young were compared with counts of capped eggs to obtain hatching success.

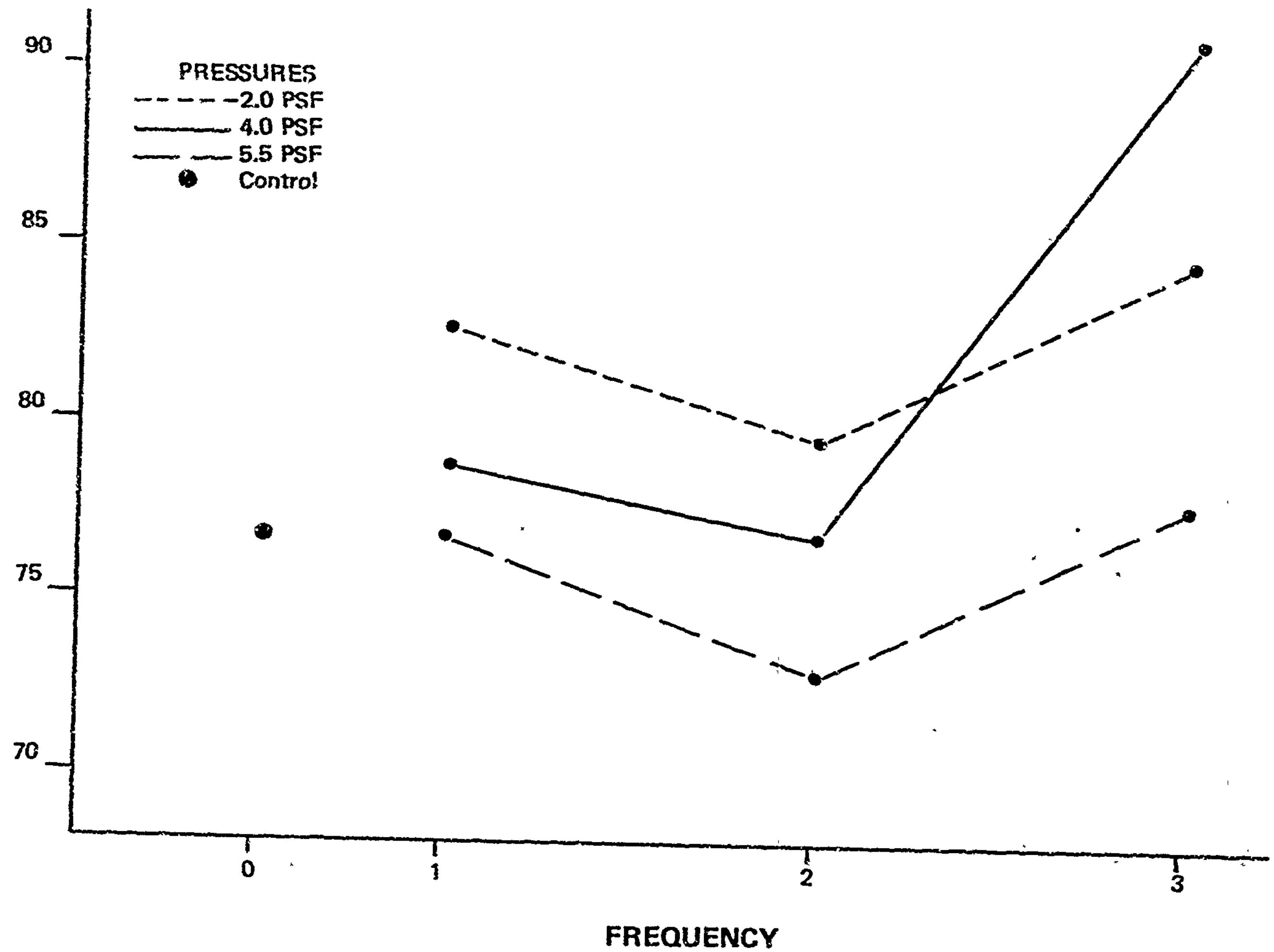


Figure 17. Hatching success of the 10 treatment groups that were subjected to various pressure regimes. There was no linearity in effects of the various pressure treatments on hatching success.

Table 1. Pressure changes of 1 pound per square foot pressure or greater on the test area as provided by FAA records from sonic boom detectors at Glen Rose and Bar L Ranch, and on the control area as inferred from detectors there.

| TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|
| Date | Number of Booms | Time | Time Interval | Number Detectors Tripped | Comments |
| February 2 | 1 (?) | 0800 hrs. | April 4-8 | 1 of 3 | |
| | 1 | 0930 hrs. | April 8-11 | 0 of 2 | |
| 5 | 1 | 1211 hrs. | April 11-16 | 1 of 3 | |
| 6 | 1 | 1412 hrs. | | | |
| 9 | 1 (?) | (?) | April 16-19 | 0 of 1 | Other detectors being repaired |
| 12 | 1 | 1549 hrs. | | | " " |
| 13 | 1 | 1053 hrs. | April 23-26 | 1 or 1 | " " |
| 20 | 1 | 0800 hrs. | April 26-30 | 1 of 3 | Tripped detector malfunctioning |
| March 2 | 1 | 1551 hrs. | | | |
| 16 | 1 | 0951 hrs. | April 30-May 3 | 1 of 2 | |
| | 1 | 1615 hrs. | May 3-7 | 1 of 3 | |
| 21 | 1 | 1356 hrs. | May 7-10 | 0 of 3 | |
| April 4 | 1 | 1653 hrs. | | | |
| 11 | 1 | 1021 hrs. | May 10-15 | 2 of 3 | Rainstorm on May 11 |
| 16 | 1 | (?) | May 15-17 | 0 of 3 | |
| 19 | 1 | 1145 hrs. | May 17-21 | 1 of 3 | |
| 27 | 1 | 1106 hrs. | May 21-24 | 0 of 4 | |
| May 2 | 1 | 1411 hrs. | May 24-27 | 4 of 4 | Thunderstorm on May 25 |
| 3 | 1 | 1205 hrs. | May 27-31 | 0 of 4 | |
| 4 | 1 | 1200 hrs. | | | |
| | 1 | 1509 hrs. | May 31-June 4 | 3 of 4 | Thunderstorm on June 3 & 4 |
| 7 | 1 | 1200-1400 hrs. | June 4-7 | 1 of 4 | |
| 9 | 1 | 1214 hrs. | June 7-11 | 0 of 4 | |
| 10 | 1 | 1141 hrs. | | | |
| 15 | 1 | 1223 hrs. | June 11-16 | 2 of 4 | |
| | 1 | 1454 hrs. | | | |
| 21 | 1 (?) | (?) | | | |
| 24 | 1 | 1206 hrs. | | | |
| 29 | 1 | 1049 hrs. | | | |
| | 1 | 1142 hrs. | | | |
| 30 | 1 | 1400 hrs. | | | |
| 31 | 1 | 1500 hrs. | | | |
| June 7 | 1 | 1605 hrs. | | | |
| 8 | 1 | 0920 hrs. | | | |
| 14 | 1 | 1206 hrs. | | | |

Table 2. Time spent in nest search and nests found per week of the four principal bird species on the test area and on the control area.

| WEEK | HOURS OF SEARCH TIME | | NEW NESTS FOUND | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mourning Dove | | Mockingbird | | Cardinal | | Lark Sparrow | |
| | Test Area | Control Area | Test Area | Control Area | Test Area | Control Area | Test Area | Control Area | Test Area | Control Area |
| April 1-7 | 16 | 14 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| April 8-14 | 16 | 14 | 1 | 18 | 0 | 1 | 0 | 0 | 0 | 0 |
| April 15-21 | 16 | 14 | 1 | 16 | 0 | 1 | 0 | 0 | 0 | 0 |
| April 22-28 | 17 | 18 | 6 | 16 | 3 | 9 | 0 | 4 | 0 | 0 |
| April 29 - May 5 | 22 | 14 | 8 | 24 | 2 | 8 | 5 | 2 | 0 | 2 |
| May 6-12 | 20 | 14 | 7 | 17 | 5 | 6 | 8 | 1 | 2 | 2 |
| May 13-19 | 23 | 14 | 5 | 21 | 5 | 4 | 5 | 1 | 3 | 5 |
| May 20-26 | 19 | 14 | 11 | 25 | 7 | 1 | 1 | 0 | 4 | 2 |
| May 27 - June 2 | 10 | 10 | 8 | 11 | 1 | 1 | 0 | 0 | 4 | 1 |
| June 2 - June 9 | 0 | 6 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | 159 | 132 | 47 | 161 | 23 | 31 | 19 | 8 | 13 | 12 |

Table 3. Relative habitat quality of the test and control areas for the four principal bird species as judged by nests found per hour of search.

| | Nests Per Hour (Habitat Quality Rating) | | Habitat Quality Ratios | |
|---|---|---|---|---|
| SPECIES | TEST | CONTROL | TEST | CONTROL |
| Mourning Dove | .32 | 1.22 | .26 | 1 |
| Mockingbird | .16 | .23 | .70 | 1 |
| Cardinal | .13 | .06 | 2.16 | 1 |
| Lark Sparrow | .09 | .09 | 1 | 1 |

Table 4. Fate of bird eggs under study on the test area and on the control area.

| APPARENT EGG FATE | MOURNING DOVE | | | | MOCKINGBIRD | | | | CARDINAL | | | | LARK SPARROW | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Test Area | | Control Area | | Test Area | | Control Area | | Test Area | | Control Area | | Test Area | | Control Area | |
| | No. | Percent | No. | Percent | No. | Percent | No. | Percent | No. | Percent | No. | Percent | No. | Percent | No. | Percent |
| Failed to hatch (Infertile, etc.) | 1 | 1.1 | 6 | 2.1 | 4 | 5.3 | 5 | 4.3 | 6 | 10.0 | 3 | 15.8 | 0 | 0.0 | 2 | 5.0 |
| Destroyed by wind, hail | 4 | 4.4 | 7 | 2.5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 4 | 8.9 | 0 | 0.0 |
| Predation upon egg | 44 | 48.3 | 77 | 27.5 | 42 | 55.2 | 33 | 28.7 | 26 | 43.3 | 8 | 42.1 | 22 | 48.8 | 26 | 65.0 |
| Abandoned by adult (egg) | 10 | 11.0 | 8 | 2.8 | 11 | 14.5 | 11 | 9.6 | 1 | 1.7 | 0 | 0.0 | 8 | 17.8 | 1 | 2.5 |
| Predation upon nestling | 5 | 5.5 | 42 | 14.9 | 8 | 10.5 | 14 | 12.2 | 6 | 10.0 | 5 | 26.3 | 7 | 15.6 | 4 | 10.0 |
| Non-predation nestling death | 1 | 1.1 | 3 | 1.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Nestling abandoned by adult | 2 | 2.2 | 6 | 2.1 | 0 | 0.0 | 3 | 2.6 | 2 | 3.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Predation upon adult | 2 | 2.2 | 35 | 12.4 | 0 | 0.0 | 4 | 3.5 | 9 | 15.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Young Fledged | 22 | 24.2 | 97 | 34.6 | 11 | 14.5 | 45 | 39.1 | 10 | 16.7 | 3 | 15.8 | 4 | 8.9 | 7 | 17.5 |
| TOTALS | 91 | 100.0 | 281 | 100.0 | 76 | 100.0 | 115 | 100.0 | 60 | 100.0 | 19 | 100.0 | 45 | 100.0 | 40 | 100.0 |

Table 5. Total nests followed to completion on the test and control areas and percent that hatched at least one egg.

| SPECIES | TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|---|
| | Number Nests Found | Hatching at least one egg | | Number Nests Found | Hatching at least one egg | |
| | | No. | Percent | | No. | Percent |
| Mourning Dove | 44 | 17 | 38.7 | 149 | 89 | 59.7 |
| Mockingbird | 24 | 8 | 33.3 | 30 | 19 | 63.3 |
| Cardinal | 20 | 10 | 50.0 | 9 | 4 | 44.5 |
| Lark Sparrow | 13 | 2 | 15.4 | 12 | 3 | 25.0 |
| Yellow-billed Cuckoo | 4 | 1 | 25.0 | 2 | 1 | 50.0 |
| Field Sparrow | 1 | 0 | 0.0 | 2 | 2 | 100.0 |
| Red-tailed Hawk | 2 | 1 | 50.0 | 1 | 1 | 100.0 |
| Great Horned Owl | 2 | 1 | 50.0 | 1 | 1 | 100.0 |
| Loggerhead Shrike | 1 | 0 | 0.0 | 4 | 3 | 75.0 |
| Western Meadowlark | 1 | 0 | 0.0 | 1 | 1 | 100.0 |
| Poor-will | 1 | 1 | 100.0 | 1 | 0 | 0.0 |
| Scissortailed Flycatcher | 3 | 1 | 33.3 | 1 | 0 | 0.0 |
| Black-chinned Hummingbird | 1 | 1 | 100.0 | - | - | - |
| TOTALS | 117 | | | 213 | | |

Table 6. Hatching success of eggs that were brooded for the normal incubation period on the test and control area.

| | TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|---|
| | Total Eggs Incubated | Eggs Hatched | Eggs That Failed To Hatch | Total Eggs Incubated | Eggs Hatched | Eggs That Failed To Hatch |
| Mourning Dove | 29 | 28 (96.6%) | 1 (3.4%) | 158 | 152 (96.2%) | 6 (3.8%) |
| Mockingbird | 23 | 19 (82.6%) | 4 (17.4%) | 57 | 52 (91.2%) | 5 (8.6%) |
| Cardinal | 31 | 24 (77.4%) | 7 (22.6%) | 8 | 7 (87.5%) | 1 (12.5%) |
| Lark Sparrow | 7 | 7 (100.0%) | 0 (0.0%) | 13 | 11 (84.6%) | 2 (15.4%) |

Table 7. Chi-square tests for differences in hatching success of bird eggs on the test and control areas.

MOURNING DOVE

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{2}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E^2)}{E}$ |
| TEST | 28 | 27.9 | .0004 | 1 | 1.1 | .0090 | 29 | .0094 |
| CONTROL | 152 | 152.1 | .0001 | 6 | 5.9 | .0020 | 158 | .0021 |
| TOTALS | 180 | 180.0 | .0005 | 7 | 7.0 | .0110 | 187 | .0115 |

Chi-square = .0115

Proportions not different at 95% confidence

MOCKINGBIRD

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 19 | 20.4 | .096 | 4 | 2.6 | .754 | 23 | .850 |
| CONTROL | 52 | 50.6 | .039 | 5 | 6.4 | .306 | 57 | .345 |
| | 71 | 71.0 | .135 | 9 | 9.0 | 1.060 | 80 | 1.195 |

Chi-square = 1.195

Proportions not different at 95% confidence

Table 7. (Continued)

CARDINAL

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 24 | 24.6 | .015 | 7 | 6.4 | .056 | 31 | .071 |
| CONTROL | 7 | 6.4 | .056 | 1 | 1.6 | .225 | 8 | .281 |
| TOTALS | 31 | 31.0 | .071 | 8 | 8.0 | .281 | 39 | .352 |

Chi-square = .352

Proportions not different at 95% confidence

LARK SPARROW

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $(0-E)^2$ |
| TEST | 7 | 6.3 | .078 | 0 | .7 | .700 | 7 | .778 |
| CONTROL | 11 | 11.7 | .042 | 2 | 1.3 | .377 | 13 | .419 |
| TOTALS | 18 | 18.0 | .120 | 2 | 2.0 | 1.077 | 20 | 1.197 |

Chi-square = 1.197

Proportions not different at 95% confidence

Table 8. Comparison of nests of four species followed to completion on the test and control areas by percentages th[illegible]ched at least one egg.

| | TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|---|
| | Nests Found | Hatching One or More Eggs | Hatching No Eggs | Nests Found | Hatching One or More Eggs | Hatching No Eggs |
| Mourning Dove | 44 | 17 (38.7%) | 27 (61.3%) | 149 | 89 (58.7%) | 60 (40.3%) |
| Mockingbird | 24 | 8 (33.3%) | 16 (66.7%) | 30 | 19 (63.3%) | 11 (36.7%) |
| Cardinal | 20 | 10 (50.0%) | 10 (50.0%) | 9 | 4 (44.5%) | 5 (55.5%) |
| Lark Sparrow | 13 | 2 (15.4%) | 11 (84.6%) | 12 | 3 (25.0%) | 9 (75.0%) |

Table 9. Chi-square tests for differences in percent of nests on the test and control areas that hatched at least one egg.

MOURNING DOVE

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 17 | 24.2 | 2.142 | 27 | 19.8 | 2.618 | 44 | 4.760 |
| CONTROL | 89 | 81.8 | .634 | 60 | 67.2 | 1.296 | 149 | 1.930 |
| TOTALS | 106 | 106.0 | 2.776 | 87 | 87.0 | 3.914 | 193 | 6.690 |

Chi-square = 6.690

Proportions different at 95% confidence

MOCKINGBIRD

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 8 | 12.0 | 1.333 | 16 | 12.0 | 1.333 | 24 | 2.666 |
| CONTROL | 19 | 15.0 | 1.067 | 11 | 15.0 | 1.067 | 30 | 2.134 |
| TOTALS | 27 | | 2.400 | 27 | | 2.400 | 54 | 4.800 |

Chi-square = 4.800

Proportions not different at 95% confidence

Table 9. (Continued)

CARDINAL

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 10 | 9.7 | .009 | 10 | 10.3 | .009 | 20 | .018 |
| CONTROL | 4 | 4.3 | .021 | 5 | 4.7 | .019 | 9 | .040 |
| TOTALS | 14 | 4.0 | .030 | 15 | 15.0 | .028 | 29 | .058 |

Chi-square = .058

Proportions not different at 95% confidence

LARK SPARROW

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 2 | 2.6 | .139 | 11 | 10.4 | .035 | 13 | .174 |
| CONTROL | 3 | 2.4 | .150 | 9 | 9.6 | .038 | 12 | .188 |
| TOTALS | 5 | 5.0 | .289 | 20 | 20.0 | .073 | 25 | .362 |

Chi-square = .362

Proportions not different at 95% confidence

Table 10. Proportions of bird eggs on the test and control areas that eventually produced fledging birds.

| | TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|---|
| | Total No. Eggs | Eggs that produced fledglings | Eggs that Failed to Produce Fledglings | Total No. Eggs | Eggs that Produced Fledglings | Eggs that Failed to Produce Fledglings |
| Mourning Dove | 91 | 22 (24.2%) | 69 (75.8%) | 281 | 97 (34.6%) | 184 (65.4%) |
| Mockingbird | 76 | 11 (14.5%) | 65 (85.5%) | 115 | 45 (39.1%) | 70 (60.9%) |
| Cardinal | 60 | 10 (16.7%) | 50 (83.3%) | 19 | 3 (15.8%) | 16 (84.2%) |
| L[illegible] Sparrow | 45 | 4 (8.9%) | 41 (91.1%) | 40 | 7 (17.5%) | 33 (82.5%) |

Table 11. Chi-square tests for differences in proportions of eggs on the test and control areas that eventually produced fledgling birds.

MOURNING DOVE

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 22 | 29.1 | 1.732 | 69 | 61.9 | .814 | 91 | 2.546 |
| CONTROL | 97 | 89.9 | .561 | 184 | 191.1 | .264 | 281 | .825 |
| TOTALS | 119 | 1190 | 2.293 | 253 | 253.0 | 1.078 | 372 | 3.371 |

Chi-square = 3.371

Proportions not different at 95% confidence.

MOCKINGBIRD

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 11 | 22.3 | 5.727 | 65 | 53.7 | 2.378 | 76 | 8.105 |
| CONTROL | 45 | 33.7 | 3.789 | 70 | 81.3 | 1.571 | 115 | 5.360 |
| TOTALS | 56 | 56.0 | 9.516 | 135 | 135.0 | 3.949 | 191 | 13.465 |

Chi-square = 13.465

Proportions different at 95% confidence.

Table 11. (Continued)

CARDINAL

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 10 | 9.9 | .0010 | 50 | 50.1 | .0002 | 60 | .0012 |
| CONTROL | 3 | 3.1 | .0032 | 16 | 15.9 | .0006 | 19 | .0038 |
| TOTALS | 13 | 13.0 | .0042 | 66 | 66.0 | .0008 | 79 | .0050 |

Chi-square = .0050

Proportions not different at 95% confidence.

LARK SPARROW

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 4 | 5.8 | .559 | 41 | 39.2 | .083 | 45 | .642 |
| CONTROL | 7 | 5.2 | .623 | 33 | 34.8 | .093 | 40 | .716 |
| TOTALS | 11 | 11.0 | 1.182 | 74 | 74.0 | .176 | 85 | 1.358 |

Chi-square = 1.358

Proportions not different at 95% confidence.

Table 12. Proportions of bird eggs on the test and control areas that failed to produce fledglings because of predation.

| | TEST AREA | | | CONTROL AREA | | |
|---|---|---|---|---|---|---|
| | Total No. Eggs | Young Development Terminated by Predation | Predation Not Incident | Total No. Eggs | Young Development Terminated by Predation | Predation Not Incident |
| Mourning Dove | 91 | 51 (56.0%) | 40 (44.0%) | 281 | 154 (54.8%) | 127 (45.2%) |
| Mockingbird | 76 | 50 (65.8%) | 26 (34.2%) | 115 | 51 (44.3%) | 64 (55.7%) |
| Cardinal | 60 | 41 (68.3%) | 19 (31.7%) | 19 | 13 (68.4%) | 6 (31.6%) |
| Lark Sparrow | 45 | 29 (64.5%) | 16 (35.5%) | 40 | 30 (75.0%) | 10 (25.0%) |

Table 13. Chi-square tests for differences in proportions of bird eggs on the test and control areas that failed to produce fledglings because of predation.

MOURNING DOVE

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 40 | 40.8 | .0157 | 51 | 50.2 | .0127 | 91 | .0284 |
| CONTROL | 127 | 126.2 | .0051 | 154 | 154.8 | .0041 | 281 | .0092 |
| TOTALS | 167 | 167.0 | .0208 | 205 | 205.0 | .0168 | 372 | .0376 |

Chi-square = .0376

Proportions not different at 95% confidence.

MOCKINGBIRD

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 26 | 35.8 | 2.683 | 50 | 40.2 | 2.389 | 76 | 5.072 |
| CONTROL | 64 | 54.2 | 1.772 | 51 | 60.8 | 1.580 | 115 | 3.352 |
| TOTALS | 90 | 90.0 | 4.455 | 101 | 101.0 | 3.970 | 191 | 8.424 |

Chi-square = 8.424

Proportions different at 95% confidence.

Table 13. (Continued)

CARDINAL

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 19 | 19.0 | 0 | 41 | 41.0 | 0 | 60 | 0 |
| CONTROL | 6 | 6.0 | 0 | 13 | 13.0 | 0 | 19 | 0 |
| TOTALS | 25 | 25 | 0 | 54 | 54 | 0 | 79 | 0 |

Chi-square = 0

Proportions not different at 95% confidence.

LARK SPARROW

| | SUCCESS | | | FAILURE | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|
| | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | E | $\frac{(0-E)^2}{E}$ | 0 | $\frac{(0-E)^2}{E}$ |
| TEST | 16 | 13.8 | .351 | 29 | 31.2 | .155 | 45 | .506 |
| CONTROL | 10 | 12.2 | .397 | 30 | 27.8 | .174 | 40 | .571 |
| TOTALS | 26 | 26.0 | .748 | 59 | 59.0 | .329 | 85 | 1.077 |

Chi-square = 1.077

Proportions not different at 95% confidence.

Table 14. Comparisons of eggs per clutch for three bird species on the test area and control area.

| MOCKINGBIRD | | CARDINAL | | LARK SPARROW | |
|---|---|---|---|---|---|
| Test Area | Control Area | Test Area | Control Area | Test Area | Control Area |
| n = 19 | n = 27 | n = 17 | n = 6 | n = 13 | n = 7 |
| 2 | 2 | 2 | 2 | 2 | 4 |
| 2 | 2 | 3 | 2 | 3 | 4 |
| 3 | 3 | 3 | 2 | 3 | 4 |
| 3 | 3 | 3 | 3 | 4 | 4 |
| 3 | 4 | 3 | 3 | 4 | 4 |
| 3 | 4 | 3 | 4 | 4 | 5 |
| 3 | 4 | 3 | | 4 | 5 |
| 3 | 4 | 3 | | 4 | |
| 3 | 4 | 3 | | 4 | |
| 4 | 4 | 3 | | 4 | |
| 4 | 4 | 3 | | 4 | |
| 4 | 4 | 3 | | 4 | |
| 4 | 4 | 4 | | 4 | |
| 4 | 4 | 4 | | | |
| 4 | 4 | 4 | | | |
| 5 | 4 | 5 | | | |
| 5 | 4 | 6 | | | |
| 5 | 4 | | | | |
| 5 | 4 | | | | |
| | 4 | | | | |
| | 4 | | | | |
| | 4 | | | | |
| | 4 | | | | |
| | 4 | | | | |
| | 4 | | | | |
| 69 | 104 | 58 | 16 | 49 | 30 |
| $\bar{X}$=3.63 | $\bar{X}$=3.85 | $\bar{X}$=3.41 | $\bar{X}$=2.67 | $\bar{X}$=3.77 | $\bar{X}$=4.29 |

Mockingbird: Means not significantly different at 95% confidence t = .168

Cardinal: Means not significantly different at 95% confidence t = .443

Lark Sparrow: Means not significantly different at 95% confidence t = .262

Table 15. Experimental design of the treatments used in the study of the effects of simulated sonic boom on hatching success of eggs of bobwhite quail. Each treatment regime consisted of three replicates of 250 eggs per replicate, except the sample treated with 5.5 PSF pressure once each day; this sample contained 675 eggs. Application of treatments began on the first day and ended on the 18th day of incubation.

| PRESSURE ($lbs/ft^2$) | FREQUENCY (NUMBER OF TREATMENTS PER 24 HOURS) 0 | 1 | 2 | 3 | Total |
|---|---|---|---|---|---|
| | 250 | | | | |
| 0 | 250 | | | | 750 |
| | 250 | | | | |
| | | 250 | 250 | 250 | |
| 2.0 | | 250 | 250 | 250 | 2,250 |
| | | 250 | 250 | 250 | |
| | | 250 | 250 | 250 | |
| 4.0 | | 250 | 250 | 250 | 2,250 |
| | | 250 | 250 | 250 | |
| | | 225 | 250 | 250 | |
| 5.5 | | 225 | 250 | 250 | 2,175 |
| | | 225 | 250 | 250 | |
| Total | | 2,175 | 2,250 | 2,250 | 7,425 |

Table 16. Number and percentage[1] of viable eggs of bobwhite quail remaining at the end of the eighth day of incubation following sonic boom treatments. All samples contained 750 eggs on the first day of incubation except the sample treated with 5.5 PSF pressure once each day; this sample contained 675 eggs.

| PRESSURE ($lbs/ft^2$) | FREQUENCY (NUMBER OF TREATMENTS PER 24 HOURS) 0 | 1 | 2 | 3 | Total | Percent |
|---|---|---|---|---|---|---|
| 0 | 622 (82.9) | | | | 622 (82.9) | 82.9 |
| 2.0 | | 659 (87.9) | 640 (85.3) | 648 (86.4) | 1,947 | 86.5 |
| 4.0 | | 644 (85.9) | 621 (82.8) | 666 (88.8) | 1,931 | 85.8 |
| 5.5 | | 575 (85.2) | 650 (86.7) | 655 (87.3) | 1,880 | 86.4 |
| Total Viable | 622 | 1,878 | 1,911 | 1,969 | 6,380 | |
| Percent Viable | 82.9 | 86.3 | 84.9 | 87.5 | 85.9 | |

[1]Percentage values are in parentheses underneath numbers viable.

Table 17. Factorial analysis of variance between survival of bobwhite quail eggs subjected to various pressure treatments.

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| All Treatment Groups | 9 | 69.988 | | |
| Control | 1 | 19.242 | 19.242 | 4.695* |
| Frequency | 2 | 19.971 | 9.986 | 2.437 |
| Pressure | 2 | 1.362 | .681 | .166 |
| Frequency X Pressure | 4 | 29.412 | 7.353 | 1.794 |
| Error | 20 | 81.962 | 4,098 | |

Table 18. Sample sizes of eggs of bobwhite quail in each replicate of the experiment after removal of infertile eggs after the eighth day of incubation. The number of eggs in the treatments of 2.0 PSF pressure and in the control were kept at 210 eggs per replicate. The number of eggs in all other treatment regimes were kept at the number of eggs that remained viable after the eighth day of incubation; i.e., the samples were not adjusted for uniformity.

| PRESSURE ($lbs/ft^2$) | 0 | FREQUENCY (NUMBER OF TREATMENTS PER 24 HOURS) 1 | 2 | 3 | Total |
|---|---|---|---|---|---|
| | 210 | | | | |
| 0 | 210 | | | | 630 |
| | 210 | | | | |
| | | 210 | 210 | 210 | |
| 2.0 | | 210 | 210 | 210 | 1,890 |
| | | 210 | 210 | 210 | |
| | | 211 | 211 | 226 | |
| 4.0 | | 213 | 198 | 215 | 1,931 |
| | | 220 | 212 | 225 | |
| | | 192 | 225 | 217 | |
| 5.5 | | 189 | 221 | 218 | 1,880 |
| | | 194 | 204 | 220 | |
| Total | 630 | 1,849 | 1,901 | 1,951 | 6,331 |

Table 19. Number and percentage of eggs of bobwhite quail that hatched following sonic boom treatments. Each sample in each replicate contained different numbers of eggs following removal of infertile eggs at the end of the eighth day of incubation. The smallest sample size in any replicate at the end of the eighth day of incubation was 189 eggs.

| PRESSURE (lbs/ft$^2$) | FREQUENCY (NUMBER OF TREATMENTS PER 24 HOURS) 0 | | 1 | | 2 | | 3 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Per. | No. | Per. | No. | Per. | No. | Per. | No. | Per. |
| 0 | 165 | 78.6 | | | | | | | 165 | 78.6 |
| | 164 | 78.1 | | | | | | | 164 | 78.1 |
| | 155 | 73.8 | | | | | | | 155 | 73.8 |
| | 484 | 76.8 | | | | | | | 484 | 76.8 |
| 2.0 | | | 180 | 85.7 | 167 | 79.6 | 170 | 80.9 | 517 | 82.1 |
| | | | 168 | 80.0 | 175 | 83.3 | 182 | 86.7 | 525 | 83.3 |
| | | | 172 | 81.9 | 159 | 75.7 | 181 | 86.2 | 512 | 81.3 |
| | | | 520 | 82.5 | 501 | 79.5 | 533 | 84.6 | 1,554 | 82.2 |
| 4.0 | | | 161 | 76.3 | 171 | 81.0 | 194 | 85.8 | 526 | 81.2 |
| | | | 185 | 86.9 | 145 | 73.2 | 202 | 94.0 | 532 | 85.0 |
| | | | 162 | 73.6 | 160 | 75.5 | 209 | 92.9 | 531 | 80.8 |
| | | | 508 | 78.9 | 476 | 76.6 | 605 | 90.8 | 1,589 | 82.3 |
| 5.5 | | | 147 | 76.6 | 183 | 81.3 | 167 | 77.0 | 497 | 78.4 |
| | | | 155 | 82.0 | 136 | 61.5 | 159 | 72.9 | 450 | 71.7 |
| | | | 138 | 71.1 | 154 | 75.5 | 182 | 82.7 | 474 | 76.7 |
| | | | 440 | 76.5 | 473 | 72.8 | 508 | 77.6 | 1,421 | 75.6 |
| Total | 484 | 76.8 | 1,468 | 79.4 | 1,450 | 76.3 | 1,646 | 84.4 | 5,048 | 79.7 |

Table 20. Factorial analysis of variance between hatching success of bobwhite quail eggs subjected to various pressure treatments.

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Control | 1 | 17.20 | 17.20 | 1.21 |
| Frequency | 2 | 175.58 | 87.79 | 6.19** |
| Pressure | 2 | 138.71 | 69.35 | 4.89 |
| Frequency X Pressure | 4 | 96.68 | 24.17 | 1.70 |
| Error | 20 | 283.82 | 14.19 | |

*denotes significance at $p = 0.05$

**denotes significance at $p = 0.01$

Table 21. Average weights of bobwhite quail hatched from eggs that had been subjected to various pressure treatments during incubation. Sample size of each mean = 25.

| Weeks | 2.0 PSF of Pressure | | | 4.0 FSF of Pressure | | | 5.5 PSF of Pressure | | | Control |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1* | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | |
| 1 | 15 | 16 | 16 | 14 | 14 | 15 | 13 | 13 | 13 | 18 |
| 2 | 29 | 29 | 30 | 25 | 32 | 30 | 26 | 24 | 27 | 30 |
| 3 | 49 | 51 | 49 | 42 | 48 | 50 | 46 | 43 | 42 | 50 |
| 4 | 70 | 73 | 72 | 67 | 65 | 70 | 67 | 59 | 70 | 78 |
| 5 | 89 | 89 | 91 | 80 | 92 | 86 | 74 | 70 | 83 | 95 |
| 6 | 112 | 107 | 109 | 96 | 103 | 103 | 87 | 86 | 96 | 101 |
| 7 | 132 | 120 | 134 | 117 | 127 | 126 | 115 | 104 | 123 | 122 |
| 8 | 147 | 155 | 146 | 132 | 132 | 142 | 125 | 117 | 132 | 141 |

*denotes number of times per day that the treatment was applied.

Table 22. Factorial analysis of variance between weights of bobwhite quail hatched from eggs subjected to various pressure treatments.

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Weeks | 7 | 13,406,613.1 | 1,915,230.4 | 1,408.8** |
| Control | 1 | 13,939.2 | 13,939.2 | 10.25** |
| Weeks X Control | 7 | 9,754.3 | 1,393.5 | 1.02 |
| Frequency | 2 | 21,390.8 | 10,695.4 | 7.87** |
| Pressure | 2 | 160,173.6 | 80,086.8 | 58.92** |
| Frequency X Pressure | 4 | 26,540.7 | 6,635.2 | 4.88** |
| Weeks X Frequency | 14 | 16,275.7 | 1,162.6 | .86 |
| Weeks X Pressure | 14 | 69,100.9 | 4,935.8 | 3.63* |
| Weeks X Frequency X Pressure[1] | 28 | 38,061.6 | 1,359.3 | |
| Total | 79 | 13,761,849.9 | | |

[1] Used as error term

Table 23. Average weights for the ninth through the twelfth week of age of bobwhite quail hatched from eggs that had been subjected to various pressure treatments during incubation. Sample size of each mean = 25.

| Week | 2.0 PSF | 4.0 PSF | 5.5 PSF | Control |
|---|---|---|---|---|
| 9 | 135 | 136 | 143 | 133 |
| 10 | 157 | 160 | 153 | 149 |
| 11 | 179 | 178 | 177 | 183 |
| 12 | 190 | 181 | 196 | 196 |

Table 24. Life tables for each of the groups of birds that were hatched from eggs subjected to four pressure regimes.

A. Control Group

| Week (x) | $l_x$ | $d_x$ | $q_x$ | $e_x$ |
|---|---|---|---|---|
| Birth | 1,000 | | | |
| 2 | 951 | 49 | 49 | 3.90 |
| 4 | 941 | 10 | 11 | 2.91 |
| 6 | 904 | 37 | 41 | 1.98 |
| 8 | 828 | 76 | 84 | 1.06 |

B. 2.0 PSF of Pressure

| Week (x) | $l_x$ | $d_x$ | $q_x$ | $e_x$ |
|---|---|---|---|---|
| Birth | 1,000 | | | |
| 2 | 955 | 45 | 45 | 3.84 |
| 4 | 930 | 25 | 26 | 2.90 |
| 6 | 880 | 50 | 53 | 1.99 |
| 8 | 814 | 66 | 75 | 1.04 |

Table 24. (Con't.)

C. 4.0 PSF of Pressure

| Week (x) | $l_x$ | $d_x$ | $q_x$ | $e_x$ |
|---|---|---|---|---|
| Birth | 1,000 | | | |
| 2 | 933 | 67 | 67 | 3.93 |
| 4 | 911 | 22 | 24 | 2.96 |
| 6 | 889 | 17 | 19 | 2.00 |
| 8 | 869 | 20 | 22 | 1.01 |

D. 5.5 PSF of Pressure

| Week (x) | $l_x$ | $d_x$ | $q_x$ | $e_x$ |
|---|---|---|---|---|
| Birth | 1,000 | | | |
| 2 | 945 | 55 | 55 | 3.80 |
| 4 | 929 | 16 | 17 | 2.82 |
| 6 | 824 | 105 | 113 | 2.04 |
| 8 | 792 | 32 | 39 | 1.02 |

Table 25. Comparison of mortality rates ($q_x$) from life tables calculated for hatchlings of bobwhite quail hatched from eggs subjected to four pressure regimes. Rates are expressed in deaths per thousand.

| Age | PRESSURES | | | |
|---|---|---|---|---|
| | Control | 2.0 PSF | 4.0 PSF | 5.5 PSF |
| 2 | 49 | 45 | 67 | 55 |
| 4 | 11 | 26 | 24 | 17 |
| 6 | 41 | 53 | 19 | 113 |
| 8 | 84 | 75 | 22 | 39 |
| Total | 185 | 199 | 132 | 224 |

Table 26. Comparison of further expectation of life ($e_x$) from life tables calculated for hatchlings of bobwhite quail hatched from eggs subjected to four pressure regimes. Ages intervals are two weeks and thus the values have been multiplied by two to obtain absolute values.

| Age | PRESSURES | | | |
|---|---|---|---|---|
| | Control | 2.0 PSF | 4.0 PSF | 5.5 PSF |
| 2 | 7.8 | 7.7 | 7.7 | 7.6 |
| 4 | 5.8 | 5.8 | 5.9 | 5.6 |
| 6 | 4.0 | 4.0 | 4.0 | 4.1 |
| 8 | 2.1 | 2.1 | 2.0 | 2.0 |